NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND

REPORT OF TEST RESULTS

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F/A-18A/B/C/D F404-GE-400/402 ENGINE SLOTTED SPRAYBAR INLET FLAMEHOLDER FOLLOW-ON FLIGHT TEST EVALUATION

by

Ms. Mary Picard
Maj. Scott Whitley, CAF

23 September 2002

DEPARTMENT OF THE NAVY
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
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SUMMARY

The current production F404-GE-400/402 flameholder (P/N 6056T68G07) experiences a high rate of replacement in the F/A-18A-D fleet. The replacement of the F404-GE–400 (-400) and F404-GE-402 (-402) flameholder requires the removal of the spraybars and support links, which can only be accomplished with the removal of the engine from the aircraft. For the -402 engine, flameholder replacement is the number one reason for unscheduled engine removals. The flameholder is exchangeable between the –402 and -400 engine, although the flameholder installed in the –402 engine has a lower life than the -400 engine flameholder because of the increased temperature severity to which the flameholder is exposed. A slotted flameholder designed to allow flameholder replacement with the engine installed in the aircraft was determined to be the best design solution. It would not require any modification to other afterburner (A/B) hardware, and after the initial installation the flameholder could be removed with the engine installed. Previous flight tests were conducted with the first version of the slotted flameholder (P/N 6056T68G10GK). Improvements to durability and operability were incorporated into the second flight test version of the slotted flameholder (P/N 6056T68G10GI) in an attempt to produce a slotted flameholder with similar durability and operability as the current production flameholder. The purpose of this flight test was to evaluate the A/B light-off performance of the slotted flameholder (P/N 6056T68G10GI) for the F/A-18A-D aircraft with F404-GE-400/402 engines. These tests were conducted from 20-28 September 2000. While evaluating the slotted flameholder, some degradation in light-off performance was observed in the upper left-hand corner of the F/A-18A-D flight envelope. However, the F/A-18A-D pilot rarely initiates A/B light-off in that portion of the envelope; therefore, A/B light-off performance was determined to be acceptable for the F/A-18A-D mission with the slotted flameholder (P/N 6056T68G10GI) installed. Recommend slotted flameholder (P/N 6056T68G10GI) be used as a replacement flameholder for the F/A-18A-D fleet.

Contents

Page No.

List of Tables

INTRODUCTION

BACKGROUND

1. The current production F404-GE-400/402 flameholder (P/N 6056T68G07) experiences a high rate of replacement in the F/A-18A-D fleet. The replacement of the F404-GE–400 (-400) and F404-GE-402 (-402) flameholders require the removal of the spraybars and support links, which can only be accomplished with the removal of the engine from the aircraft. For the -402 engine, flameholder replacement is the number one reason for unscheduled engine removals. The flameholder is exchangeable between the –402 and -400 engine, although the flameholder installed in the –402 engine has a lower life than the -400 engine flameholder because of the increased temperature severity to which the flameholder is exposed. A slotted flameholder designed to allow flameholder replacement with the engine installed in the aircraft was determined to be the best design solution. The slotted flameholder was designed to be physically interchangeable with –400 and –402 engine models. It would not require any modification to other afterburner (A/B) hardware, and after the initial installation, flameholder removal would not require the removal of the spraybars and the support links. Therefore, the engine does not have to be removed to install or remove the slotted flameholder. Conversion of the slotted flameholder back to the current production flameholder is also possible but an engine removal is required. Durability and operability were intended to be as good as the current production flameholder. The improved maintainability will reduce aircraft downtime during a flameholder change since the engine will remain in the aircraft and is not inducted into the Aircraft Intermediate Maintenance Department (AIMD) Jet Shop. By preventing an induction, engine downtime and the overall cost of the flameholder replacement is reduced. Also, since spraybars and fuel lines are not disconnected while changing out a slotted flameholder, a Functional Check Flight (FCF) is not required after a slotted flameholder change.

2. The first test version of the slotted flameholder (P/N 6056T68G10GK) was flight tested in June 1999. Although the slotted flameholder design had not demonstrated satisfactory durability in the test cell, an initial look at operability in flight was desired. Results indicated that light-off performance, or operability, of the first flight test version slotted flameholder was not as good as the production flameholder in the upper left-hand corner of the flight envelope. Details of that flight test are covered in reference 1. After completing durability improvements, General Electric (GE) provided a second flight test version (P/N 6056T68G10GI) which incorporated changes making durability and operability, in the test cell, comparable to the production flameholder. NAWCAD Patuxent River, Maryland, was tasked by reference 2 to perform A/B light-off performance testing of the slotted flameholder (P/N 6056T68G10GI) installed in an F404-GE-400/402 engine. A Test Reports/Deliverables Plan is presented as appendix A.

PURPOSE

3. The purpose of this flight test was to evaluate the A/B light-off performance of the slotted flameholder (P/N 6056T68G10I) for the F/A-18A-D aircraft with F404-GE-400/402 engines.

DESCRIPTION OF TEST AIRCRAFT/SYSTEMS

TEST AIRCRAFT

4. The F/A-18 is a high performance, twin-engine, afterburning, carrier-based supersonic fighter attack airplane, available in either single-seat or two-seat configurations, manufactured by Boeing. A detailed description of the F/A-18 aircraft is contained in reference 3. The test aircraft for this test was a Naval Strike Aircraft Test Squadron (NSATS) F/A-18C SD104, BuNo 164869. The test aircraft was considered to be production representative for the purpose of these tests.

TEST ENGINES

5. The test F/A-18 was powered by two Enhanced Performance Engines (EPE's)/F404-GE-402 engines manufactured by GE. The F404-GE-402 is an augmented low-bypass turbofan engine that incorporated a 3-stage fan and a 7-stage compressor, each driven by a single stage turbine. A hydraulically actuated hinged-flap cam-linked Variable Exit Nozzle (VEN) modulates to optimize thrust and stall margin in response to pilot throttle commands. EPE engines were chosen because a higher bypass ratio, an increased temperature and an increased velocity in the A/B cause the flameholder to be more difficult to light-off when compared to -400 engines. The port (test) engine used during testing was S/N 360127, which had approximately 520 hr engine operating time (EOT) and 220 EOT since the last production flameholder replacement. The starboard engine was S/N 360408 with approximately 1,340 hr EOT at the start of testing and 390 EOT since the last flameholder replacement.

ENGINE SCHEDULING AND AFTERBURNER LIGHT-OFF PERFORMANCE

6. Light-off times for FI-MAX A/B transients are typically slower than MIL-MAX A/B transients due to vapor puff elimination logic in the electrical control assembly (ECA) logic. The ECA holds fuel flow demand to 20.5 ratio units during high altitude (above 11,000 ft) FI-MAX A/B transients to prevent an A/B initiation (5.5 ratio units is required to allow A/B initiation) until fan speed is within 3% of the fan speed limit. This ensures A/B operation will not be initiated until the temperature is hot enough to properly burn the A/B fuel. An A/B slow or no light is usually attributed to either a transient scheduling problem or an initial light-off problem. The transient schedule problem is a mismatch between the nozzle and fuel flow schedules, which results in the A/B blowing out after it lights. An initial light-off problem is a flameholder design issue where the flameholder geometry is not conducive to lighting off.

SLOTTED FLAMEHOLDER

7. The slotted flameholder (P/N 6056T68G10GI) featured slotted inlets for the spraybars, as shown in figure B-1, and new support links attached to the flameholder with breakable bolts, as shown in figure B-2. These features allowed easy removal of the flameholder with the engine installed in the aircraft, as shown in figure B-3. The spraybar slotted inlets allowed the flameholder to be slid out from the spraybars without removing individual spraybars. Figure B-4

shows the slotted flameholder design while figure B-5 shows the production flameholder for comparison. The breakable bolt is overtorqued to failure to allow the flameholder to be removed. One piece of the bolt is captured in the hook nut of the support link and subsequently removed prior to the next flameholder installation. The other half of the bolt is retained in the flameholder by self-capture threads and is removed with the flameholder. This process is shown in figure B-6 and described in appendix C. New bolts and hook nuts are required for a slotted flameholder installation.

SLOTTED FLAMEHOLDER REMOVAL/INSTALLATION

8. Installation of the slotted flameholder for these tests required the removal of the engine in order to remove the old flameholder and its support links. The slotted flameholder, with new links, was then installed in the conventional manner. A removal/installation of the slotted flameholder with the engine remaining in the aircraft was not part of this evaluation, therefore; after flight tests, the engine was removed and the slotted flameholder was converted back to the current production flameholder. For the purposes of this test, the installation/removal of the slotted flameholder followed normal production flameholder maintenance procedures, reference 4. Additionally, the pilot and main spraybars were inspected in accordance with I-level maintenance procedures and no cracking was detected before the slotted flameholder was installed.

FLIGHT TEST SLOTTED FLAMEHOLDER CONFIGURATION (P/N 6056T68G10GI)

9. The slotted flight test flameholder configuration is shown in table 1.

Table 1: Flight Test Slotted Flameholder Configuration (P/N 6056T68G10GI)

Part	Slotted Flameholder Configuration (P/N 6056T68G10GI)	Purpose for Changes
Outer Shell	Same as production – one piece 45 mil thick – except for a racetrack shaped hole for the basket casting versus a circular shape for the production.	The racetrack shaped hole accommodates the removable support link concept.
Inner Shell	One piece 45 mil thick versus production two piece with 30 mil thick forward section and 45 mil thick rear section	Cost reduction. Increased durability.
Blocker Tubes	Eliminated tubes at six pilot spray bar locations. Blocker tubes on either side of the pilot spray bar locations have been reduced from 0.400 to 0.250 in. (18 tubes total).	The six tubes were eliminated to accommodate the slot clips. The other tubes were reduced in size to eliminate wake recirculation that causes internal burning – increased durability.
Inlet Lip	Increased inlet lip gap from the production 0.30 to 0.32 in.	Maintain original airflow – light-off performance.
Spraybar Holes	Slotted with clips versus production race track configuration	Allows the flameholder to be slid off the spraybars and removed while engine is installed in aircraft – increased maintainability.
Support Links	The link arm is fabricated from a production R41 casting with the holes ¼ in. closer together. The fixed inner clevises have been replaced by insert castings that mate to the new basket castings that are part of the flameholder assembly. Six breakable bolts and hooknuts are used to join the inserts and baskets together.	Allows the flameholder to be removed with the engine in the aircraft – increased maintainability.

DURABILITY AND OPERABILITY AT GENERAL ELECTRIC

10. GE conducted durability and operability tests of the second flight test version slotted flameholder (P/N 6056T68G10GI) back-to-back with a production flameholder (P/N 6056T68G07) in their test cell and found this slotted flameholder to be comparable to the production, as reported in reference 5. The second flight test version slotted flameholder (P/N 6056T68G10GI) also showed slightly improved durability and operability in the test cell compared to the first flight test version (P/N 6056T68G10GK). Operability testing was conducted at sea-level static and at simulated altitude. Durability testing determined the number of A/B light-offs until physical failure of the flameholder. New, zero-time slotted flameholders were installed for flight tests. After flight tests were finished, both flight test versions were returned to GE and tested to failure, in the test cell. Both obtained 602 total lights (including flight tests and test cell runs), slightly higher than seen on the test cell only slotted flameholders. Table 2 shows a summary of the durability results.

Table 2: Durability of Flight Test Version Slotted Flameholders
Compared to a Production Flameholder

Flameholder Configuration	P/N	No. of A/B Lights
Production (Test Cell Only)	6056T68G07	686
First Flight Test (Test Cell Only)	6056T68G10GK	513
Second Flight Test (Test Cell Only)	6056T68G10GI	595
First Flight Test (Flight Test/Test Cell)	6056T68G10GK	602(1)
Second Flight Test (Flight Test/Test Cell)	6056T68G10GI	602(1)

NOTE: (1) Number of A/B lights achieved is a combination of lights obtained during flight tests and subsequent test cell durability testing.

LOADING

11. The aircraft loading for the slotted test flights and baseline flight is shown in table 3.

Table 3: Aircraft Loading

Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
LAU-7	Clean	Clean	Missile Well Cover	SUU-62 Pylon and 330-gal EFT	Missile Well Cover	Clean	Clean	LAU-7

TEST CONFIGURATIONS

12. All test points were flown with landing gear up and auto flaps. Speedbrake was not used for any test points. Table 4 shows the flameholder test configuration for each flight.

Table 4: Flameholder Test Configuration

Flight No.	Purpose	Port Engine Flameholder	Starboard Engine Flameholder
1, 2, and 3	Test Slotted Flameholder	Slotted (P/N 6056T68G10GI)	Production (P/N 6056T68G07)
4	Baseline	Production (P/N 6056T68G07)	Production (P/N 6056T68G07)

SCOPE OF TESTS

TESTS AND TEST CONDITIONS

13. A total of four flights was flown for 4.6 hr, not including two FCF's required after flameholder changes. Table 5 has the breakdown of the flights. The hot pits were used for refueling between flight Nos. 1 and 2. Cold ambient temperature was targeted for all test points and is defined in Test Criteria, in paragraph 14. All tests were conducted within the flight restrictions of the F/A-18A-D NATOPS Manual, reference 3, and NAVAIRSYSCOM flight clearance, appendix D. The Target Test and Test Conditions Matrices are presented in tables E-1 and E-2.

Table 5: Flameholder Test Flight Breakdown

Flight No.	Date	Purpose	Length (hr)
1	20 Sep 2000	Slotted Flameholder Test Flight	1.1
2	20 Sep 2000	Slotted Flameholder Test Flight	1.1
3	21 Sep 2000	Slotted Flameholder Test Flight	1.1
4	28 Sep 2000	Baseline Flight	1.3

TEST CRITERIA

14. Slow lights and no lights thresholds were the same as used in previous flameholder tests, references 1, 6, 7, and 8 and are shown in table 6. Acceptable light-off performance was based on light-off performance as good as the production flameholder and as defined in table 6. Cold ambient temperature was defined as T1 less than –50°C at 40,000 ft Hp/100 KCAS.

Table 6: A/B Light-Off Test Criteria

Transient	Slow Light (sec) Test Criteria	No Light (sec)	
		Test Criteria	Engine Spec (see note)
FI-MAX	≥9	≥20	≥15
MIL-MAX	≥6	≥15	≥6

NOTE: No light criteria for the upper left corner of the engine envelope from paragraph 3.2.1.5.6 of the Model Specification for the engine, reference 9. These times are listed for reference only and were not considered test criteria.

METHOD OF TESTS

TEST METHOD AND PROCEDURES

15. The slotted flameholder test flights were flown prior to the baseline test flights for convenience since the airplane was already down for maintenance. The slotted flameholder was installed in the port engine, which was the same engine used in the previous slotted flameholder flight testing, reference 1. The starboard engine contained a production flameholder and neither the starboard engine nor the flameholder was the same as installed for the previous flight tests. After an FCF was flown, the test points, presented in table E-1 were accomplished. The hot pits were used and testing occurred in the inshore areas. The port engine was then removed and sent to the AIMD Jet Shop to replace the slotted flameholder with the production flameholder. After the engine was reinstalled in the aircraft, an FCF was flown. The baseline test points, presented in table E-2, were completed during one flight.

16. Dual snap throttle transients from military power (MIL) and flight idle (FI) to maximum A/B were performed straight and level to determine A/B light-off times. All throttle transients were performed first with bleed air in NORM. For slow lights, no lights, or blowouts, the test point was repeated with bleed air OFF for the affected engine. For the reasons described in paragraph 6, a MIL-MIN A/B transient was also performed at some of those conditions to determine if the anomaly was a transient scheduling problem or an initial light-off problem. Test conditions targeted the high altitude, slow speed portion of the aircraft flight envelope with an occasional spot check of the remaining flight envelope. Test point buildup was from low to high altitude and from fast to slow airspeed. Test points were performed after the engine had stabilized at the test power setting, either MIL or FI. Stabilization was defined as an exhaust gas temperature (EGT) rate of change of less than 5 deg/sec. Flying qualities effects prevented some of the slow airspeed test points from achieving stabilization prior to selection of A/B.

COLD AMBIENT TEMPERATURE AT ALTITUDE

17. Light-off performance decreases with decreasing temperature; therefore, cold ambient temperature during testing was desired (T1 < –50°C at 40,000 ft Hp/100 KCAS). The baseline flight and most of the slotted flameholder flights did not meet the cold ambient temperature requirements. The test plan called for points to be repeated with bleed OFF on the non-test engine, which would increase the severity on the test flameholder similar to a decrease in temperature. However, the test team and GE decided to not repeat the points since the test flameholder was already experiencing slow and no lights.

INSTRUMENTATION AND DATA EXTRACTION/PROCESSING

18. All required measurands were selected from the aircraft 1553 Mux Bus data stream; no analog measurands were required. A Digital Data Acquisition System instrumentation/data system package was used to extract the data from the Mux Bus. Measurands consisted of engine operability parameters, flight conditions and Hot Mic as shown in table E-3. Data were

telemetered for real-time monitoring and recorded via onboard data recorder for postflight download and analysis.

LESSONS LEARNED

19. Table E-4 contains the hazard analysis performed for this test program. None of the hazards identified were encountered during testing. A/B no lights and blowouts were experienced but the pilot was prepared for them and was able to counter the resulting yawing moment with about ½ - ¾ rudder pedal input. The lessons learned during this testing pertain to test quality and efficiency rather than test safety. Lessons learned were identified in four areas: baseline testing, inlet temperature, test technique, and bleed air setting. Detailed explanation of the lessons learned is contained in appendix F.

CHRONOLOGY

20. A chronology of events is as follows:

a.	Original slotted flameholder test plan approved	7 May 1999
b.	Test plan amendment No. 1 approved	23 June 1999
c.	Test plan amendment No. 2 (second flight test version slotted flameholder) approved	9 August 2000
d.	Port engine removed and slotted flameholder installed	13-15 September 2000
e.	Port engine installed in test aircraft with slotted flameholder	17 September 2000
f.	Test plan amendment No. 3 approved	18 September 2000
g.	FCF	19 September 2000
h.	Flight Nos. 1 and 2 – slotted flameholder	20 September 2000
i.	Flight No. 3 – slotted flameholder	21 September 2000
j.	Port engine and slotted flameholder removed; Production flameholder installed	22-25 September 2000
k.	Port engine installed in test aircraft with production flameholder	26 September 2000
l.	FCF	27 September 2000
m.	Flight No. 4 – baseline	28 September 2000

TEST TEAM MEMBERS

21. The following people were on the Slotted Flameholder Flight Test Team:

Mary Picard	4.11.5.1	NAVAIR Patuxent River	Lead Project Engineer
Maj. Scott Whitley	5.5.3.1	NAVAIR Patuxent River	Project Officer (CAF)
Maj. Greg Bigalk	5.5.3.1	NAVAIR Patuxent River	Project Pilot
Gary Waller	5.4.2.2	NAVAIR Patuxent River	Instrumentation Technician
Doug Risling	5.5.3	NAVAIR Patuxent River	Project Liaison Office Rep.
Jan Baney	4.11.5.1	NAVAIR Patuxent River	Project Engineer (Test Conductor)
Tim Andryzak	4.11.5.1	NAVAIR Patuxent River	Project Engineer
John Boyden	--	General Electric	Patuxent River Technical Rep.
Todd Perzanoski	--	General Electric	Afterburner Group Engineer
Wayne Oliver	--	General Electric	Afterburner Group Engineer

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RESULTS AND EVALUATION

GENERAL

LIGHT-OFF PERFORMANCE VERSUS INLET TEMPERATURE

22. Previous testing, references 1, 7, and 8 has shown that light-off times increased as inlet temperature decreased, therefore; an inlet temperature of colder than –50°C at 40,000 ft Hp/100 KCAS was desired for these tests. Temperatures between –44°C and –50°C were observed at flight conditions near 40,000 ft Hp/100 KCAS. These temperatures were not quite as cold as desired, but it was decided real-time not to repeat the test points with the bleed OFF on the non-test engine. During all flights, the range of inlet temperatures tested was from 35°C at the center of the envelope out to –56°C in the upper left-hand corner. The lowest T1 temperatures recorded, at any conditions, during baseline and slotted flameholder test flights were -48°C and -56°C, respectively. Light-off performance was normalized by comparing light-off time to inlet temperature. Since inlet temperatures less than –48°C were not encountered during the baseline test, temperatures less than –48°C could not be compared directly between the baseline test and slotted flameholder tests. Additionally, the starboard engine consistently recorded inlet temperatures 1-2°C warmer than the port engine during both baseline and slotted flameholder test flights. This temperature difference between engines might be attributable to sensor or control system tolerances.

U.S. NAVY FLEET AFTERBURNER USAGE IN THE UPPER LEFT-HAND CORNER OF FLIGHT ENVELOPE

23. After the tests, GE analyzed the F/A-18 mission analysis data for the U.S. Navy. It was determined that the fleet operates less than 1% of the time in the region found during testing with the most light-off anomalies, above 40,000 ft Hp from 0.4 to 0.6M. Additionally, pilot experience indicates that if they are operating in that area, they are already in A/B and rarely select A/B in that region.

BASELINE TESTING

GENERAL

24. A baseline flight was conducted with production flameholders installed in each engine. The test matrix, table E-2, was completed for the baseline flight and was a subset of the slotted flameholder test matrix, table E-1. Transients from FI-MAX A/B and MIL-MAX A/B were performed by stabilizing on the test conditions in the initial throttle setting and then performing a dual snap transient into MAX A/B. For some test points, the aircraft did not have enough power to maintain the flight conditions while performing the throttle transient. In these cases, A/B was selected and held until light-off even if the aircraft was outside the test tolerances by the time an A/B light-off was achieved.

MIL-MAX AFTERBURNER THROTTLE TRANSIENTS

25. Table E-5 contains the MIL-MAX A/B time-to-light data for the baseline flight. Light-offs were achieved for all the test points attempted on both flameholders. Marginally slow lights (6.1 sec) were observed on both flameholders (test point 8); however; they were not considered significant due to being only 1/10 of a second over the slow light boundary. The aircraft flight envelope, with MIL-MAX A/B throttle transients mapped on it, is shown in figures B-7 and B-8 for the port and starboard production flameholders, respectively. Figures B-9 and B-10 show the time-to-light versus inlet temperature for MIL-MAX A/B transients for the port and starboard engines respectively. The port flameholder showed a slightly larger spread in light-off times as compared to the starboard flameholder as shown by comparing Figures B-9 and B-10. For both flameholders all the light-off times were under 3 sec except for one slow light on the starboard flameholder (test point 8) and two test points on the port flameholder (test points 8 and 41). While the port flameholder was slightly slower in light-off times as compared to the starboard flameholder over the range of inlet temperatures tested (-26°C to –47°C), the light-off times met the test criteria for good lights. For MIL-MAX A/B transients, the port and starboard production flameholders demonstrated satisfactory light-off performance over the –26°C to –47°C inlet temperature range and were considered to have production representative A/B light-off performance.

FI-MAX AFTERBURNER THROTTLE TRANSIENTS

26. Table E-5 contains the FI-MAX A/B time-to-light data for both flameholders for the baseline flight. Light-offs were achieved for all of the test points attempted on both flameholders except for one no-light on the port flameholder (test point 40). The test point was repeated (40R1) and resulted in a slow light on the port flameholder. Three other slow lights on the port flameholder (test points 24, 44, and 38) and one slow light on the starboard flameholder (test point 40R1) were experienced. Figures B-11 and B-12 show the port and starboard production flameholder test points mapped on the flight envelope for the FI-MAX A/B transients. The 1g decel line is mapped on the left-hand portion of the envelope. Outside of this line, the pilot cannot maintain airspeed and altitude at 1g. All FI-MAX A/B transient light-off anomalies are in the 1g decel area. Figures B-13 and B-14 show the time-to-light versus inlet temperature for FI-MAX A/B transients for the port and starboard engines, respectively. The data shows as inlet temperatures decreased from –20°C to -40°C time-to-light increased slightly for both engines. The port flameholder has slightly slower light-off times for FI-MAX A/B transients than the starboard flameholder at inlet temperatures colder than -40°C. For FI-MAX A/B transients, the port flameholder was slower to light-off at temperatures between –40°C and –47°C but was still satisfactory. At inlet temperatures above –40°C, the port and starboard engine FI-MAX A/B light-off performance was comparable and satisfactory. For FI-MAX A/B transients, the port and starboard production flameholders demonstrated satisfactory light-off performance over the -25°C to –47°C inlet temperature range and were considered to have production representative A/B light-off performance.

SLOTTED FLAMEHOLDER TESTING

GENERAL

27. Slotted flameholder test flights were conducted with the slotted flameholder installed in the port engine and a production flameholder installed in the starboard engine. The entire test matrix was completed except the supersonic test point No. 21 as shown in table E-1. Transients from FI-MAX A/B and MIL-MAX A/B were performed by stabilizing on the test conditions in the initial throttle setting and then performing a snap transient into MAX A/B. Center of the envelope test points were only performed with MIL-MAX A/B throttle transients, as indicated in table E-1, to spot check the flight envelope. Slow light, no light, and blowout test points were repeated, with bleed air OFF on the engine experiencing the anomalous A/B light. Additionally, selected test points were repeated with a MIL-MIN A/B transient and bleed air NORM to help determine the cause of the light-off problem.

MIL-MAX AFTERBURNER THROTTLE TRANSIENTS

28. Table E-6 contains the MIL-MAX A/B time-to-light data for both engines for the slotted flameholder flights. Light-offs were achieved for all the test points attempted on both engines except for one test point, 23R1, on the slotted flameholder which achieved a light-off after the 15 sec no-light boundary. Additionally, two slow lights (test points 25 and 31R1) and several blowouts (test points 25, 33, 31 and 30M) on the slotted flameholder and one slow light (test point 23) on the starboard production flameholder were experienced. The starboard production flameholder also had one additional slow light, test point 31R1, with the port bleed air OFF. This bleed setting is considered worst case for A/B light-off performance and is not factored in the starboard production flameholder's light-off performance. Test points that resulted in slotted flameholder light-off anomalies were repeated with the port engine bleed air selected OFF. On test point 31R1 the starboard production flameholder still lit quicker than the slotted flameholder. The aircraft flight envelope, with MIL-MAX A/B throttle transients mapped on it, is shown in figures B-15 and B-16 for the slotted flameholder and starboard production flameholder, respectively. All MIL-MAX A/B transient light-off anomalies are in the 1g decel area. Figures B-17 and B-18 show the time-to-light versus inlet temperature for MIL-MAX A/B transients for the slotted flameholder and the starboard production flameholder, respectively. For temperatures –47°C and warmer, light-off times were comparable on the slotted test flights to the baseline test flights as shown by comparing figures B-17 to B-9 and figures B-18 to B-10. For temperatures colder than –47°C, comparing figures B-17 to B-18 showed a greater increase in A/B light-off times and more blow-outs on the slotted flameholder. The slotted flameholder had ten test points slower than three seconds compared to two on the starboard production flameholder. The slotted flameholder experienced five blow-outs compared to none on the starboard production flameholder. The MIL-MAX A/B light-off performance of the slotted flameholder (P/N 6056T68G10GI) was marginally degraded from the performance of the starboard production flameholder (P/N 6056T68G07). Minor degradation in the MIL-MAX A/B light-off capability of the slotted flameholder (P/N 6056T68G10GI) occurred in the extreme upper left-hand corner of the F/A-18A-D flight envelope (40,000 ft Hp and higher with less than 0.5 IMN); however, this is a region the F/A-18 pilot rarely flies and the impact to the F/A-18

mission is negligible. The MIL-MAX A/B light-off performance of the slotted flameholder (P/N 6056T68G10GI), for the F/A-18A-D mission, was satisfactory.

FI-MAX AFTERBURNER THROTTLE TRANSIENTS

29. Table E-6 contains the FI-MAX A/B time-to-light data for both engines for the slotted flameholder flights. Light-offs were achieved for all of the test points attempted on both flameholders except for two test points, 30 and 46, on the slotted flameholder which achieved a light-off after the 20 sec no-light boundary. Additionally, the slotted flameholder experienced twelve slow lights (test points 26, 24, 22, 22R1, 34, 34R1, 30R1, 24, 40, 40R1, 38, and 38R1) and three blowouts (test points 24, 32, and 39). The starboard engine with the production flameholder experienced only three anomalies, all slow lights, test points 32, 46, and 40, with the bleed air set in NORM. It had five additional slow lights, test points 34R1, 32R1, 30R1, 40R1, and 38R1, when the port bleed air was OFF. This bleed setting is considered worst case for A/B light-off performance and is not factored in the starboard production flameholder’s light-off performance. Test points that resulted in slotted flameholder light-off anomalies were repeated with the port engine bleed air selected OFF. On test points 26R1, 22R1, 34R1, 46R1, and 40R1 the starboard production flameholder still lit quicker than the slotted flameholder. Figures B-19 and B-20 show the slotted and starboard production flameholder test points mapped on the flight envelope for the FI-MAX A/B transients. Only one slow light, test point 26, on the slotted flameholder is not inside the 1g decel area. Figures B-21 and B-22 show the time-to-light versus inlet temperature for FI-MAX A/B transients for the slotted flameholder and the starboard production flameholder engines respectively. For temperatures –47°C and warmer, light-off times were comparable on the slotted test flights to the baseline test flights as shown by comparing figures B-21 to B-13 and figures B-22 to B-14. On both flights the port engine flameholder had more slow lights than the starboard flameholder as the temperatures approached –47°C. For temperatures colder than –47°C, comparing figures B-21 to B-22, and discounting the slow lights with opposite bleed OFF, showed a greater increase in A/B light-off times and more blow-outs on the slotted flameholder. The majority of the slotted flameholder test points were slow lights in this temperature region while the starboard production engine only had two slow lights without port bleed OFF. The slower light-off times associated with colder temperatures corresponds to higher altitude and slower airspeeds. Based upon a mission analysis (discussed in paragraph 23), the flight conditions where the light-off anomalies are concentrated are in a region of the flight envelope that an F/A-18 pilot will rarely fly, and the probability of being in this region while at FI is even more rare, therefore; the impact to the F/A-18 mission is negligible. Minor degradation in the FI-MAX A/B light-off capability of the slotted flameholder (P/N 6056T68G10GI) occurred in the extreme upper left-hand corner of the F/A-18A-D flight envelope (40,000 ft Hp and higher with less than 0.6 IMN); however, this is a region the F/A-18 pilot rarely flies and the impact to the F/A-18 mission is negligible. The marginal FI-MAX A/B light-off performance of the slotted flameholder (P/N 6056T68G10I) in the upper left-hand corner of the F/A-18 envelope has a negligible impact to the F/A-18 mission.

MIL-MIN AFTERBURNER THROTTLE TRANSIENTS

30. Selected FI-MAX A/B test points with slow lights or no lights were repeated with MIL-MIN A/B throttle transients. The purpose of this was to help determine if the light-off problem was a transient scheduling problem or an initial light-off problem as discussed in paragraph 6. Table E-6 shows the data for the MIL-MIN A/B transient test points. The test point numbers correspond to the initial test point that had the anomaly requiring the repeat. The MIL-MIN A/B light-off times were similar to the MIL-MAX A/B light-off times. This shows that the problem was an initial light-off problem associated with the flameholder design. The longer light-off times on the slotted flameholder instead of quick light-offs with subsequent blowouts indicates that the light-off anomalies were due to the slotted flameholder design.

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CONCLUSIONS

GENERAL

31. The slotted flameholder (P/N 6056T68G10I) is satisfactory for the F/A-18A-D aircraft mission.

SPECIFIC

32. For MIL-MAX A/B transients, the port and starboard production flameholders demonstrated satisfactory light-off performance over the –26°C to –47°C inlet temperature range and were considered to have production representative A/B light-off performance (paragraph 24).

33. For FI-MAX A/B transients, the port and starboard production flameholders demonstrated satisfactory light-off performance over the –25°C to –47°C inlet temperature range and were considered to have production representative A/B light-off performance (paragraph 25).

34. Minor degradation in the MIL-MAX A/B light-off capability of the slotted flameholder (P/N 6056T68G10GI) occurred in the extreme upper left-hand corner of the F/A-18A-D flight envelope (40,000 ft Hp and higher with less than 0.5 IMN); however, this is a region the F/A-18 pilot rarely flies and the impact to the F/A-18 mission is negligible (paragraph 27).

35. The MIL-MAX A/B light-off performance of the slotted flameholder (P/N 6056T68G10GI), for the F/A-18A-D mission, was satisfactory (paragraph 27).

36. Minor degradation in the FI-MAX A/B light-off capability of the slotted flameholder (P/N 6056T68G10GI) occurred in the extreme upper left-hand corner of the F/A-18A-D flight envelope (40,000 ft Hp and higher with less than 0.6 IMN); however, this is a region the F/A-18 pilot rarely flies and the impact to the F/A-18 mission is negligible (paragraph 28).

37. The marginal FI-MAX A/B light-off performance of the slotted flameholder (P/N 6056T68G10I) in the upper left-hand corner of the F/A-18 envelope has a negligible impact to the F/A-18 mission (paragraph 28).

38. The longer light-off times on the slotted flameholder, instead of quick light-offs with subsequent blowouts, indicates that the light-off anomalies were due to the slotted flameholder design (paragraph 29).

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RECOMMENDATION

39. Recommend slotted flameholder (P/N 6056T68G10GI) be used as a replacement flameholder for the F/A-18A-D fleet.

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REFERENCES

1. NAVAIRWARCENACDIV Patuxent River Report of Test Results No. NAWCADPAX--99-169-RTR, F/A-18A/B/C/D/F404-GE-400/402 Engine Slotted Spraybar Inlet Flameholder Flight Test Evaluation, of 14 Oct 1999.

2. NAVAIRSYSCOM Project Unit: W1355, Program Element 0205633N, Aircraft Engine Component Improvement Program, Document No. N0001900CIPAD01, of 22 Nov 1999.

3. NATOPS Flight Manual, Model F/A-18A/B/C/D, A1-F18AC-NFM-000, Change 6 of 15 Feb 2000.

4. Technical Manual Intermediate Maintenance Turbofan Engine Models F404-GE-400 and F404-GE-402, AI-F404A-MMI-210 (Vol. 3), of 1 Mar 1993, with Change 6 of 1 Sep 1999, WP 50 01 Intermediate Maintenance Disassembly of A/B Module F404-GE-402, WP 50 04 Intermediate Maintenance Assembly of A/B Module F404-GE-402, and WP 52 01 Inspection and Repair of Flameholder.

5. Engineering Change Proposal G404-A-38, Afterburner Flameholder Maintainability Improvement, of 31 Jan 2001.

6. Flight Test and Engineering Group Technical Report No. SA-25R-94, Modified Flameholder for the F404-GE-400 Engine, of 22 Mar 1994.

7. NAVAIRTESTCEN Technical Report No. SA-149R-91, Modified Flameholder Evaluation for the F404-GE-400 Engine as Installed in the F/A-18, of 9 Dec 1991.

8. NAVAIRTESTCEN Technical Report No. SA-93R-90, Evaluation of the GE Air Cooled and P&W Production Flameholder for the F404-GE-400 Engine, of 5 Dec 1990.

9. Model Specification for the F404-GE-400 Turbofan Engine, CP45K0006, of Feb 1983.

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APPENDIX A
TEST REPORTS/DELIVERABLES PLAN

07-Aug-00 12:22pm From-NAWCAD +3017570542 T-089 P.02/02 F-372

TEST REPORTS/DELIVERABLES PLAN

Test Program/Project:	F/A-18C/D/F404-GE-402 Slotted Flameholder Flight Test Evaluation
Applicable Requirements Document, TEMP, AIRTASK/Work Unit, etc.:	Airtask# A4444C/053D/9W 13550000
Sponsor/Customer Team Representative (Name, Code, Telephone):	Mr. Luke Helbling, Air 4.4, 301-757-0341
NAWCAD Test Team Representative (Name, Code, Telephone):	Mary Picard, 4.11.5.1, 301-757-0674

TAILORED REQUIREMENTS LIST:

DELIVERABLE (Report Number)	DEL TIMING (Target Date) (Actual Date)	CONFIGURATION or FORMAT	REMARKS
E-mail test summary	1 week after test	E-mail text	Notice of test completion & Preliminary Results
Report	3 months after flights completed	Report of Test Results	Final test results and recommendations

DATE APPROVED: 8-7-00

FOR NAWCAD TEST TEAM: Mary B. Picard

FOR SPONSOR/CUSTOMER TEAM: Lu Helbling

11

Amendment 2
Enclosure (4)

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APPENDIX B
FIGURES

List of Figures

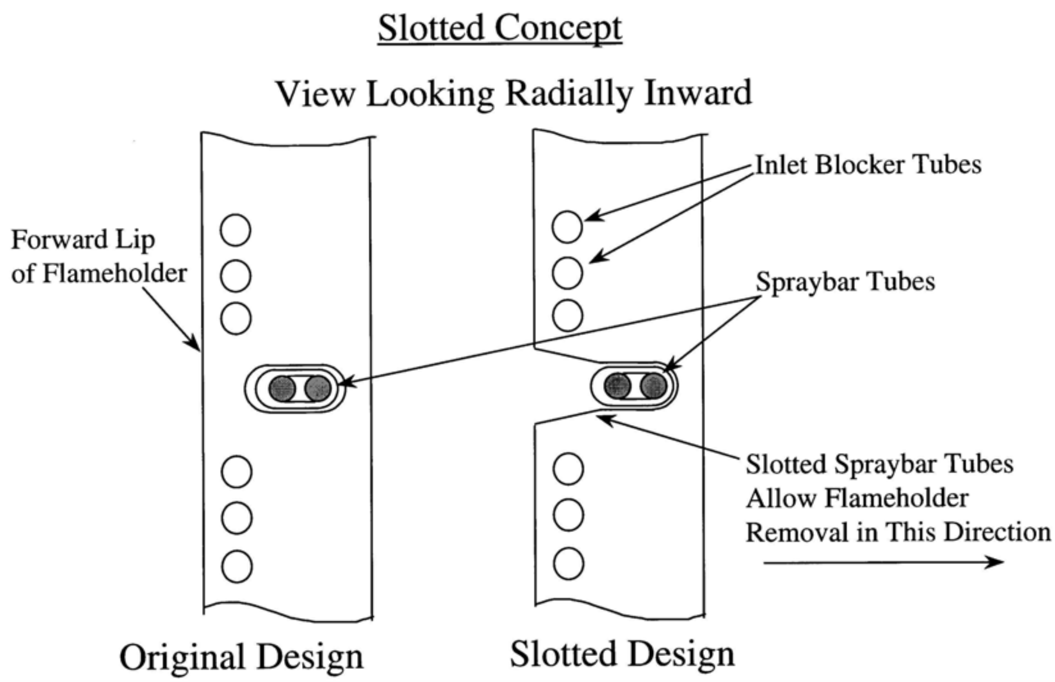
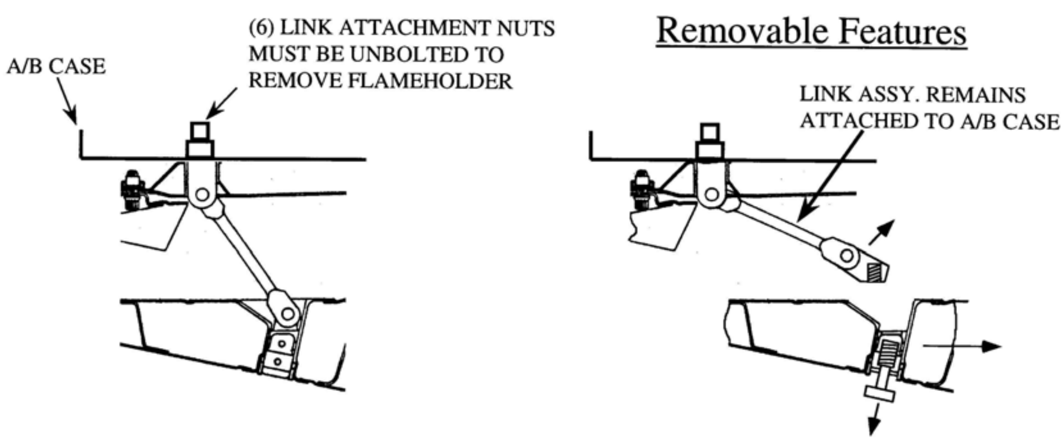


Figure B-1: Production Racetrack versus Slotted Spraybar Inlets



Production Slotted

Figure B-2: Production versus Slotted Flameholder Support Links

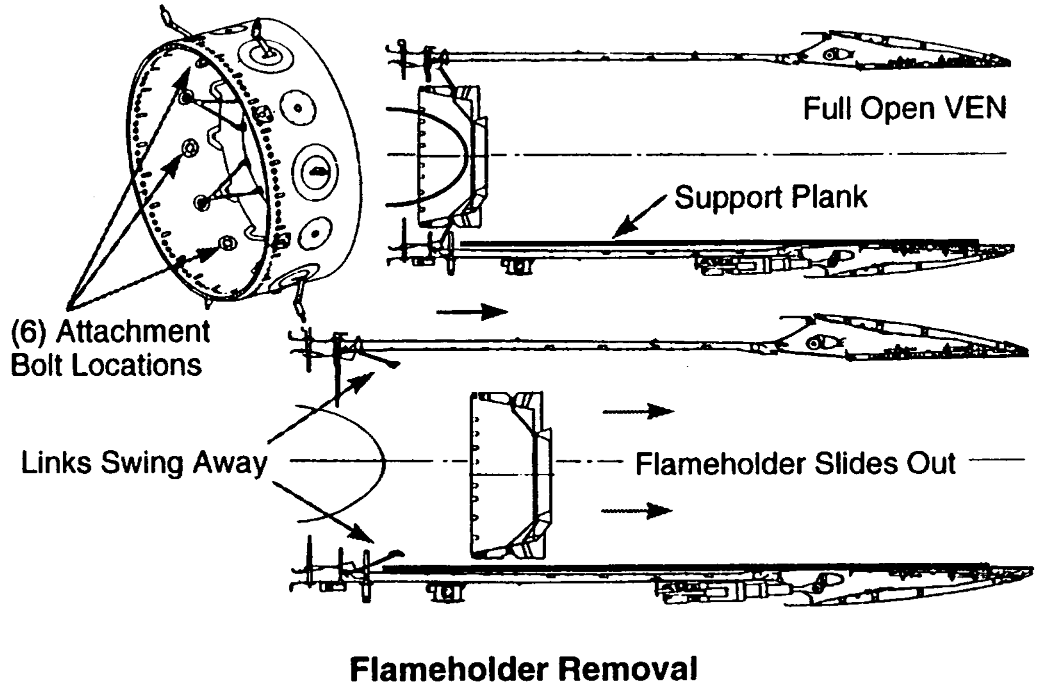


Figure B-3: Slotted Flameholder Removal Process

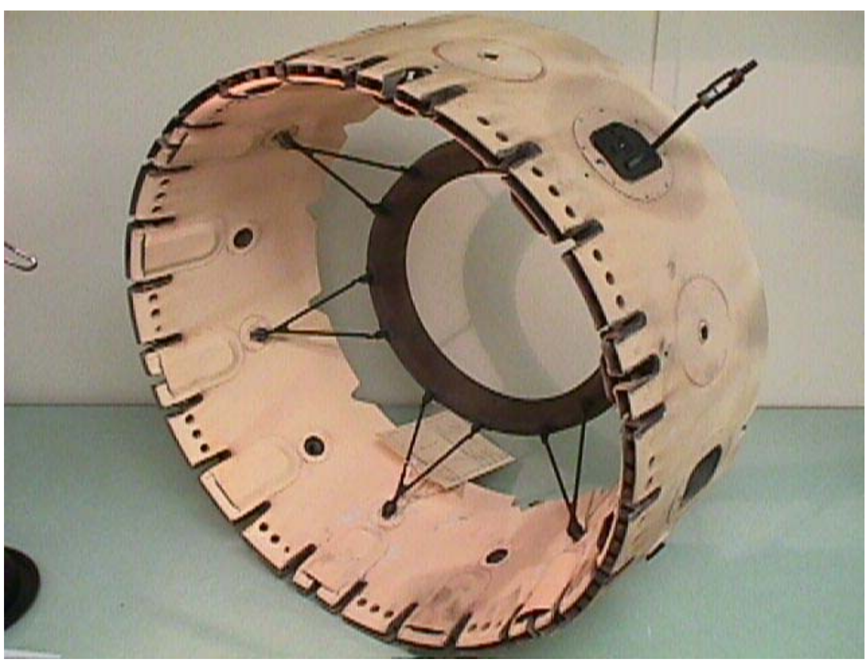


Figure B-4: Flameholder with Slotted Spraybar Inlets (Only One Support Link Attached)

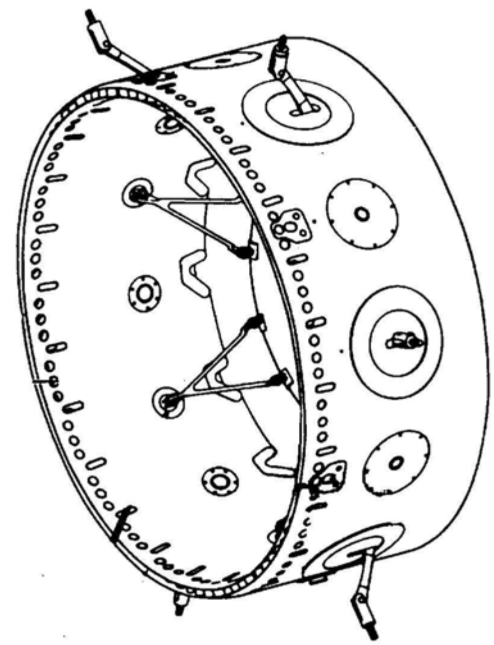


Figure B-5: Production Flameholder with Racetrack Spraybar Inlets

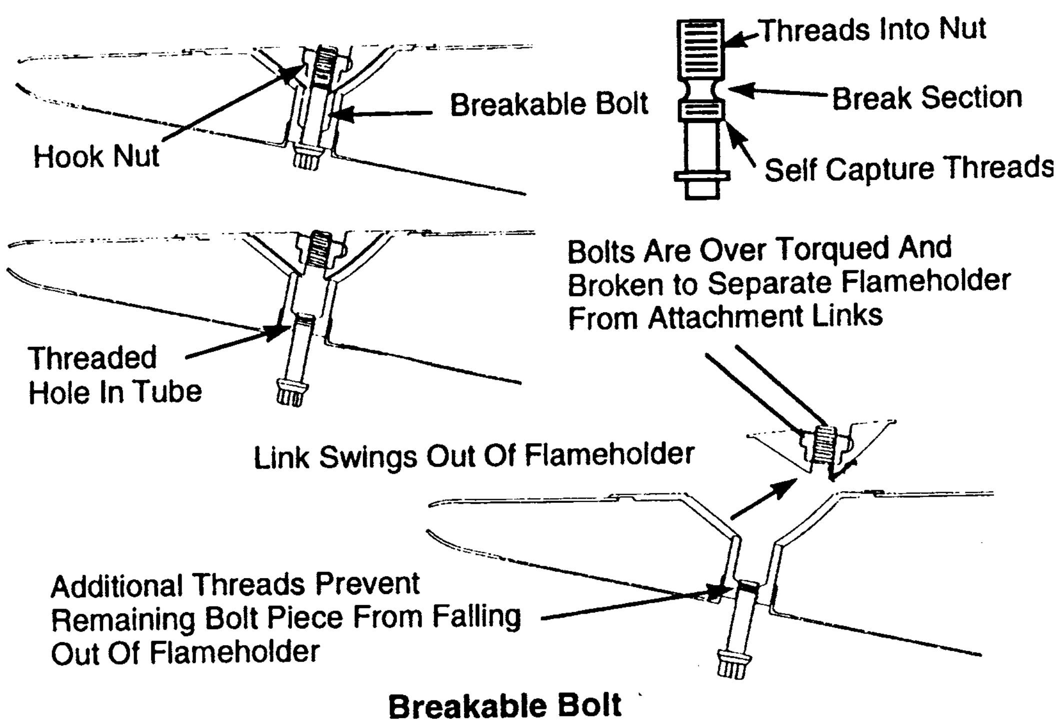


Figure B-6: Breakable Bolt Process

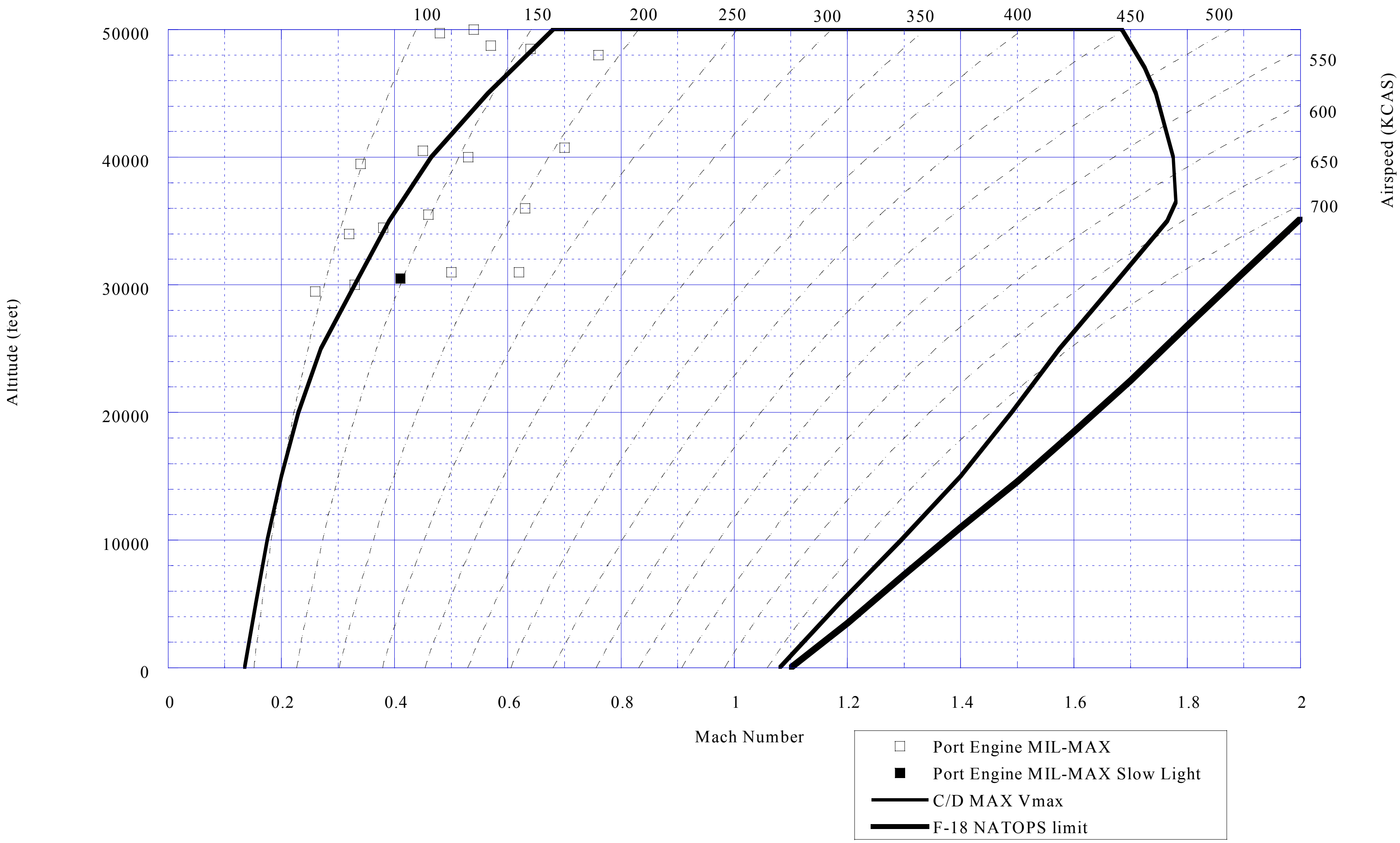


Figure B-7: F/A-18 Flight Envelope with MIL-MAX A/B Light-Off Test Points
Port Engine (S/N 360127), Production Flameholder (P/N 6056T68G07)
Baseline - Flight No. 4

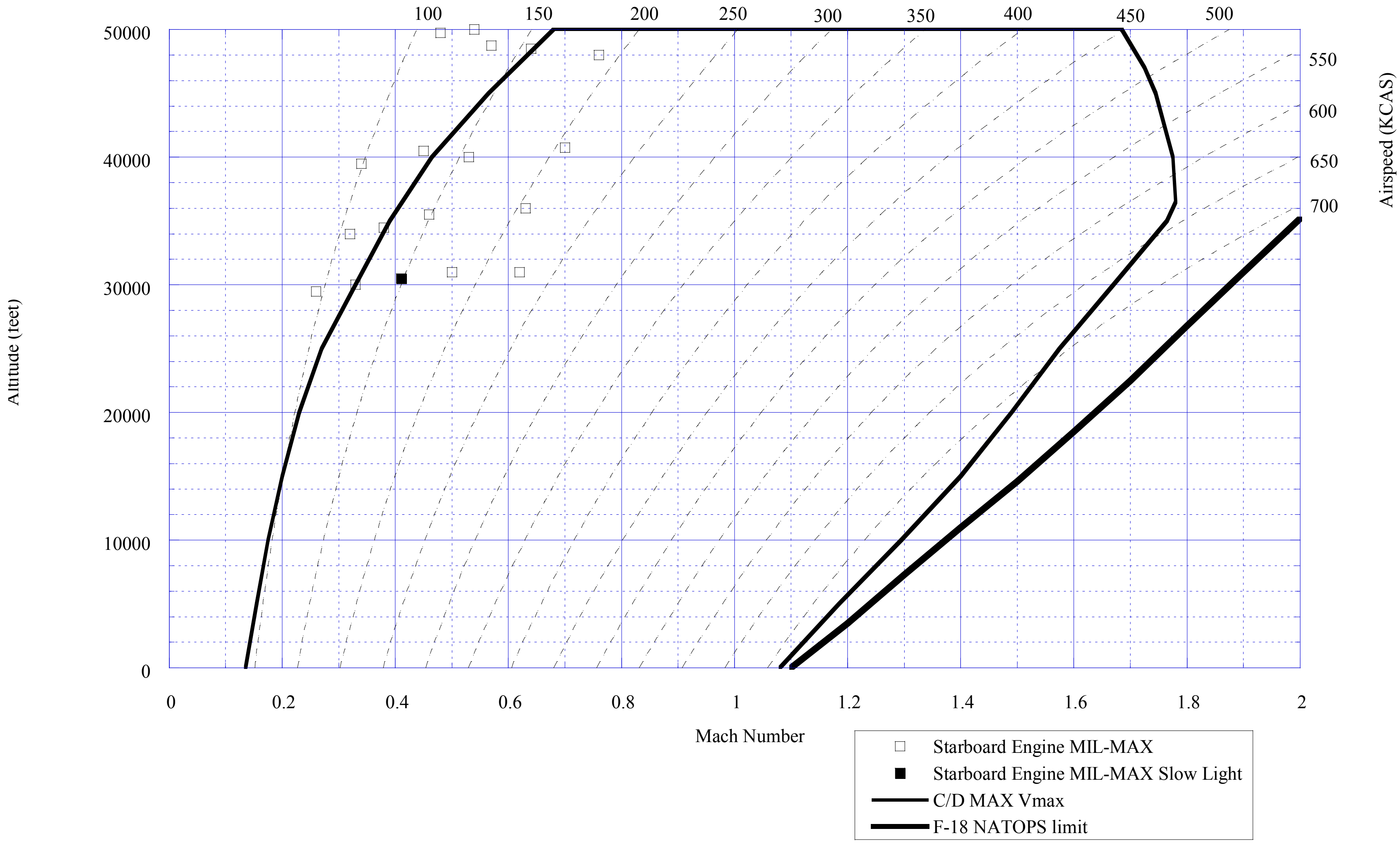


Figure B-8: F/A-18 Flight Envelope with MIL-MAX A/B Light-Off Test Points
Starboard Engine (S/N 360408), Production Flameholder (P/N 6056T68G07)
Baseline - Flight No. 4

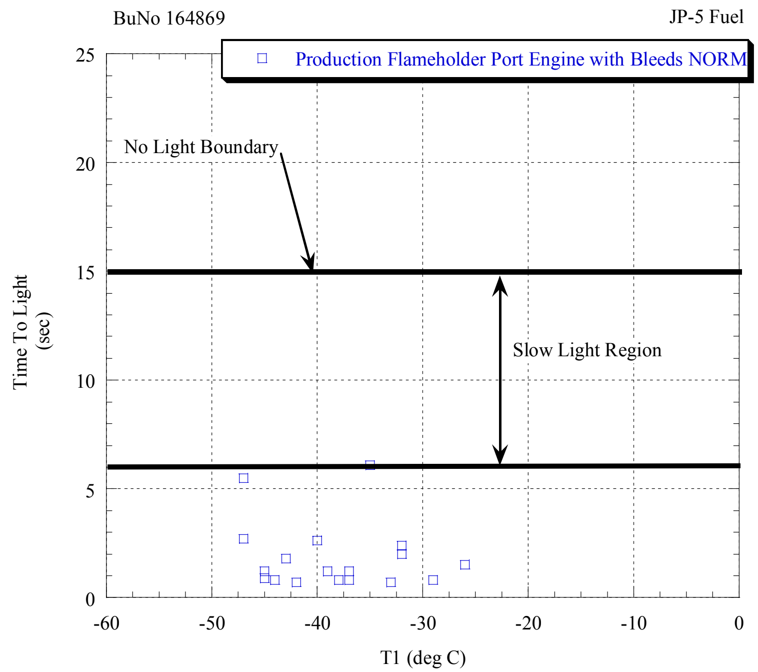


Figure B-9: Time-to-Light Versus Inlet Temperature at Light-Off
Port Engine (S/N 360127)
Production Flameholder (P/N 6056T68G07)
Baseline – Flight No. 4
MIL-MAX A/B Transients

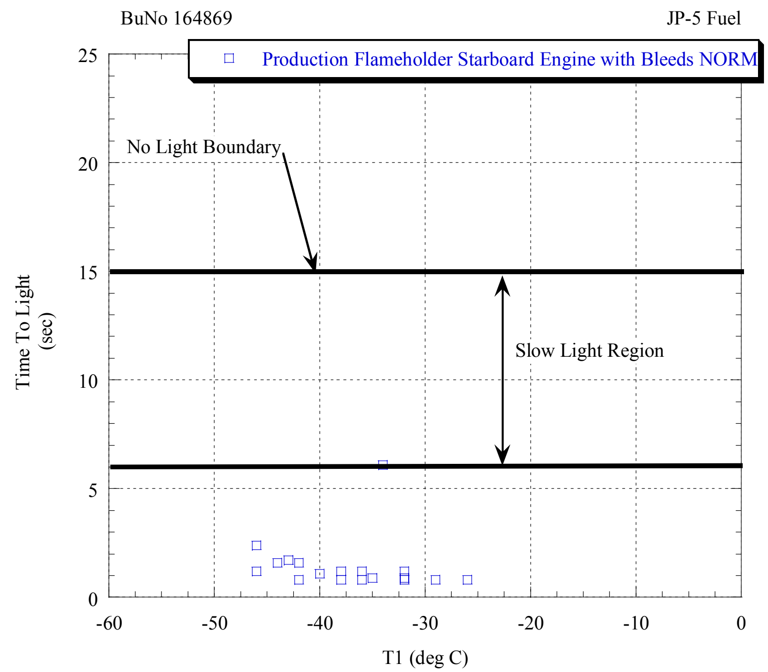


Figure B-10: Time-to-Light Versus Inlet Temperature at Light-Off
Starboard Engine (S/N 360408)
Production Flameholder (P/N 6056T68G07)
Baseline – Flight No. 4
MIL-MAX A/B Transients

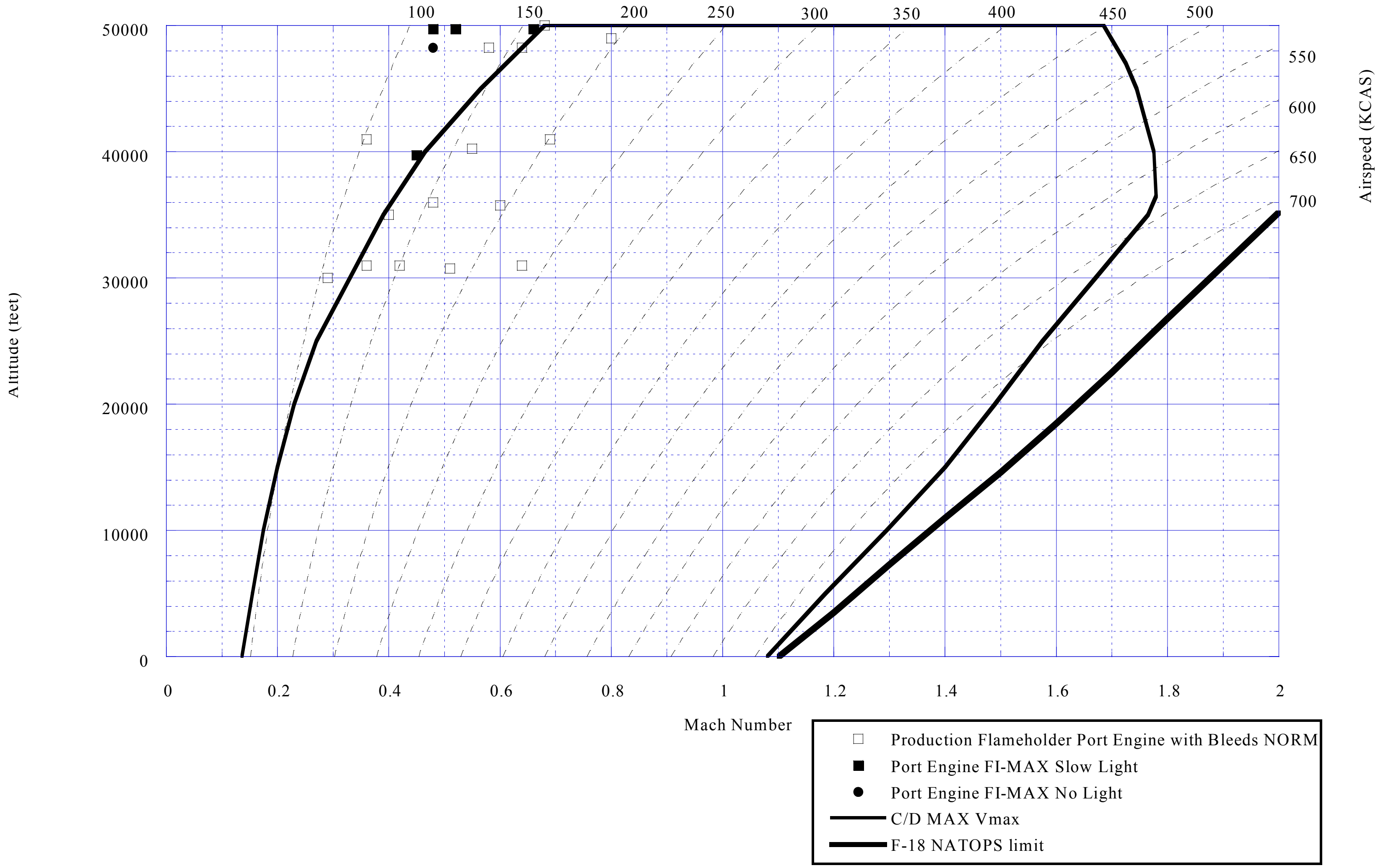


Figure B-11: F/A-18 Flight Envelope with FI-MAX A/B Light-Off Test Points
Port Engine (S/N 360127), Production Flameholder (P/N 6056T68G07)
Baseline - Flight No. 4

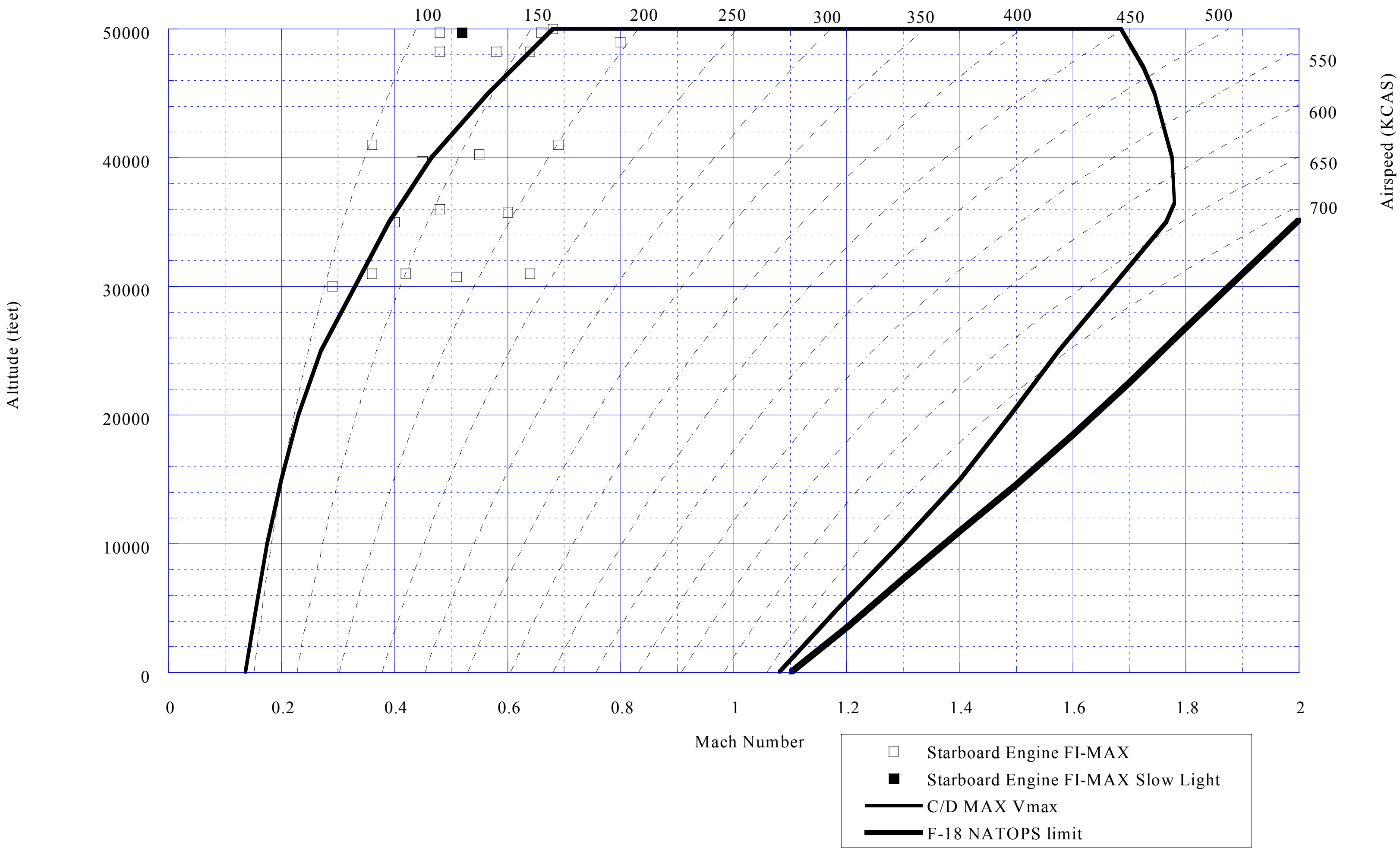


Figure B-12: F/A-18 Flight Envelope with FI-MAX A/B Light-Off Test Points
Starboard Engine (S/N 360408), Production Flameholder (P/N 6056T68G07)
Baseline - Flight No. 4

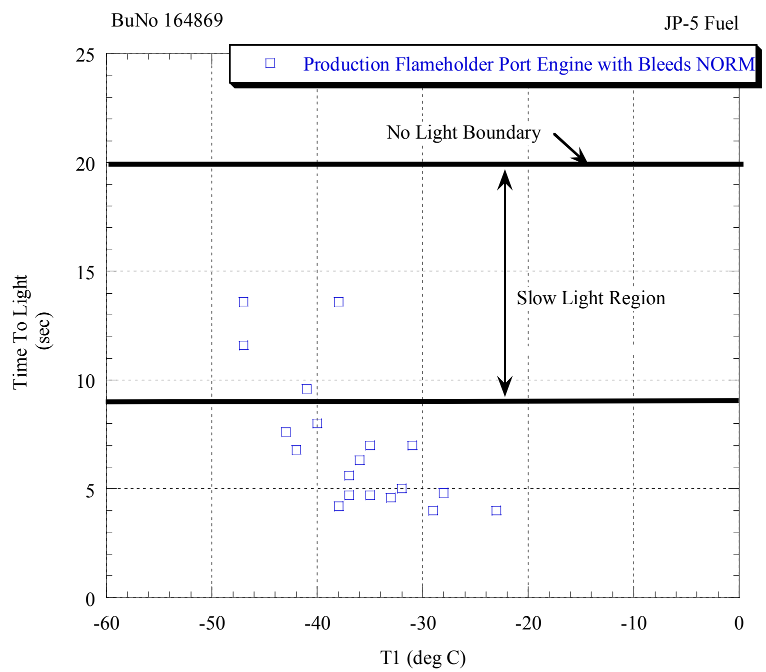


Figure B-13: Time-to-Light Versus Inlet Temperature at Light-Off
Port Engine (S/N 360127)
Production Flameholder (P/N 6056T68G07)
Baseline – Flight No. 4
FI-MAX A/B Transients

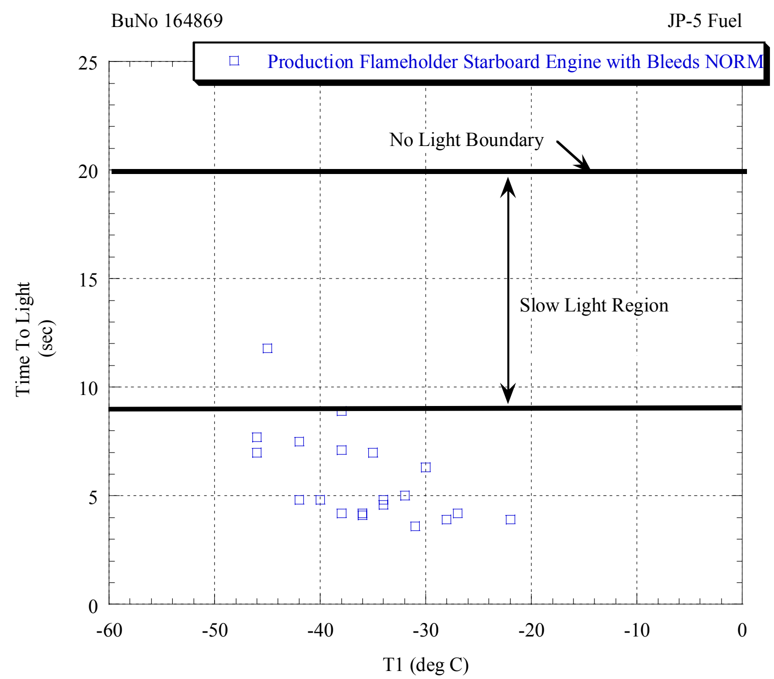


Figure B-14: Time-to-Light Versus Inlet Temperature at Light-Off
Starboard Engine (S/N 360408)
Production Flameholder (P/N 6056T68G07)
Baseline – Flight No. 4
FI-MAX A/B Transients

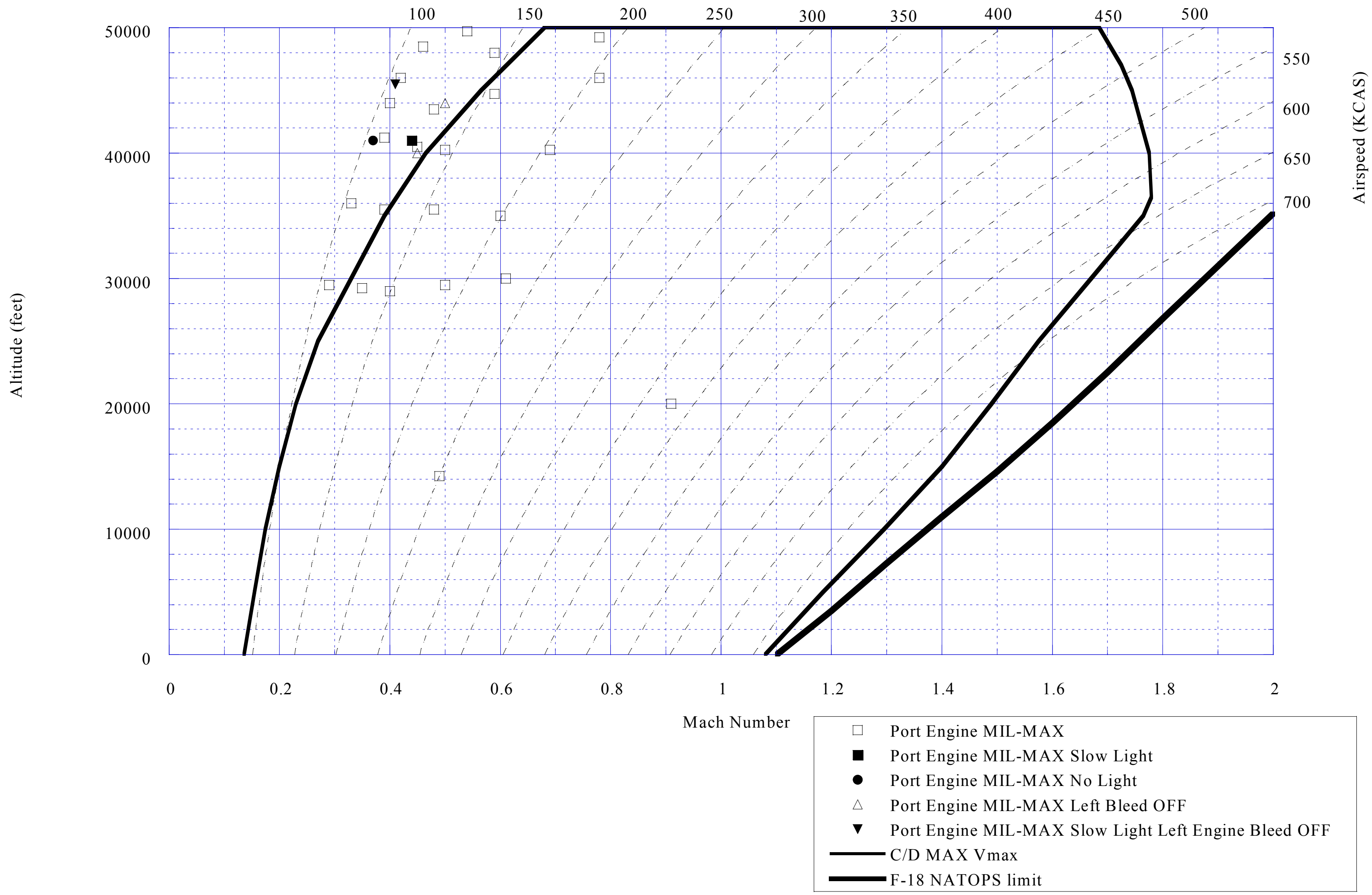


Figure B-15: F/A-18 Flight Envelope with MIL-MAX A/B Light-Off Test Points
Port Engine (S/N 360127), Slotted Flameholder (P/N 6056T68G10GI)
Flight Nos. 1, 2, and 3

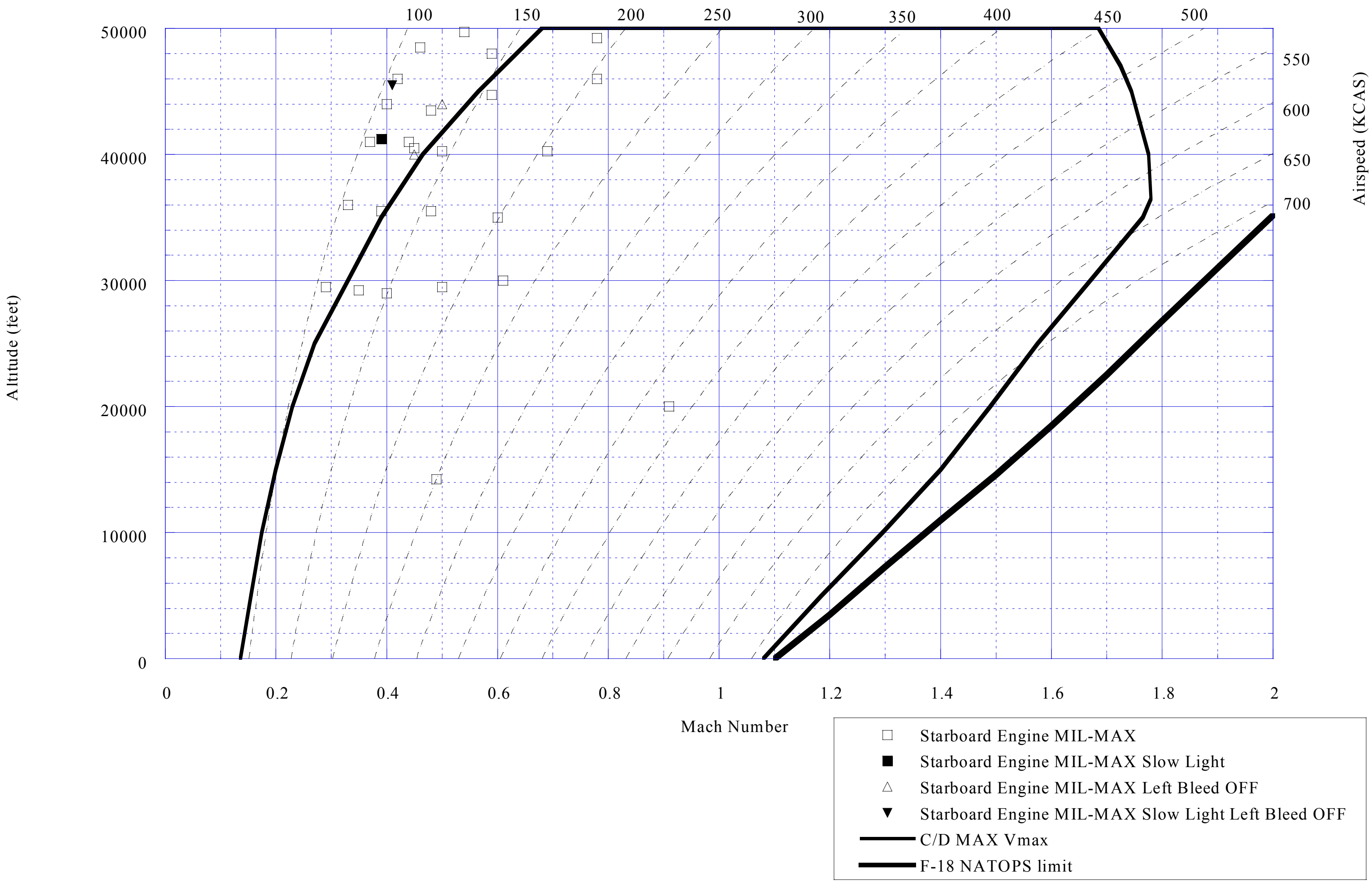
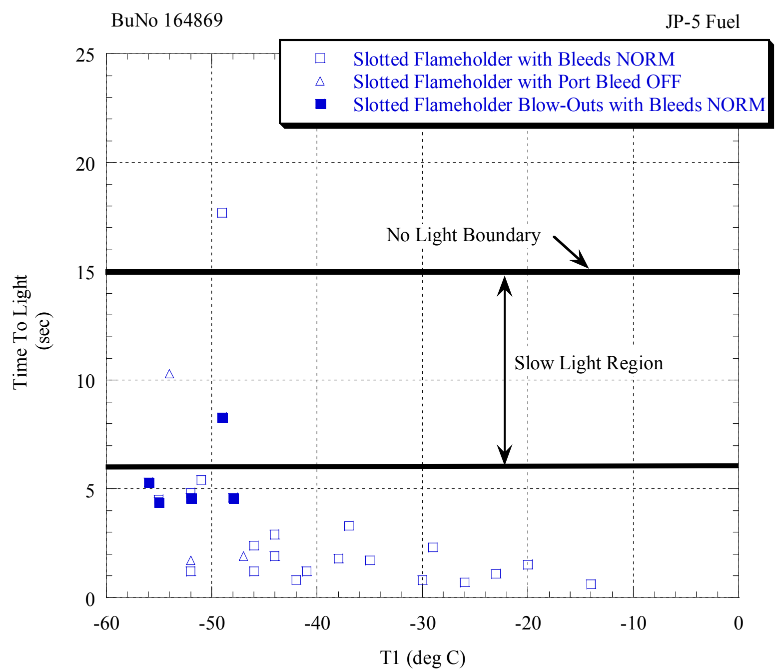


Figure B-16: F/A-18 Flight Envelope with MIL-MAX A/B Light-Off Test Points
Starboard Engine (S/N 360408), Production Flameholder (P/N 6056T68G07)
Flight Nos. 1, 2, and 3



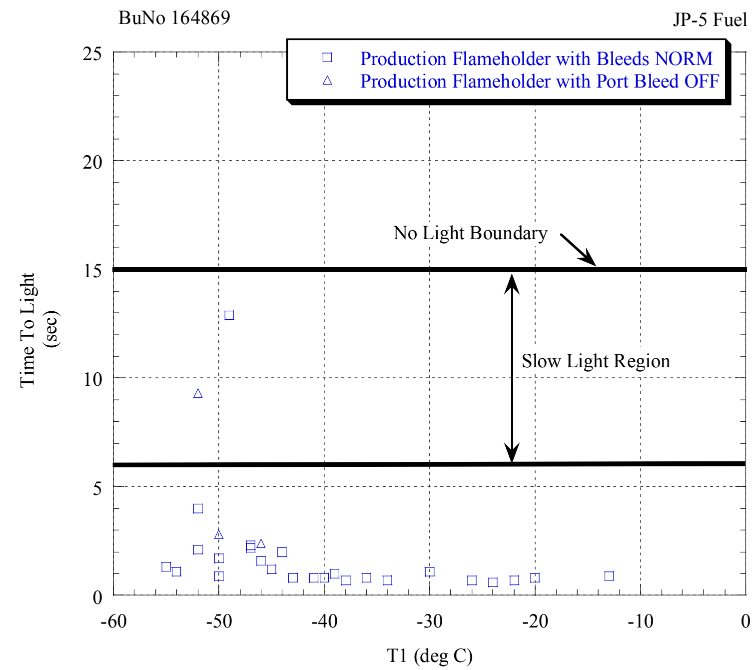


Figure B-17: Time-to-Light Versus Inlet Temperature at Light-Off
Port Engine (S/N 360127)
Slotted Flameholder (P/N 6056T68G10GI)
Flight Nos. 1, 2, and 3
MIL-MAX A/B Transients

Figure B-18: Time-to-Light Versus Inlet Temperature at Light-Off
Starboard Engine (S/N 360408)
Production Flameholder (P/N 6056T68G07)
Flight Nos. 1, 2, and 3
MIL-MAX A/B Transients

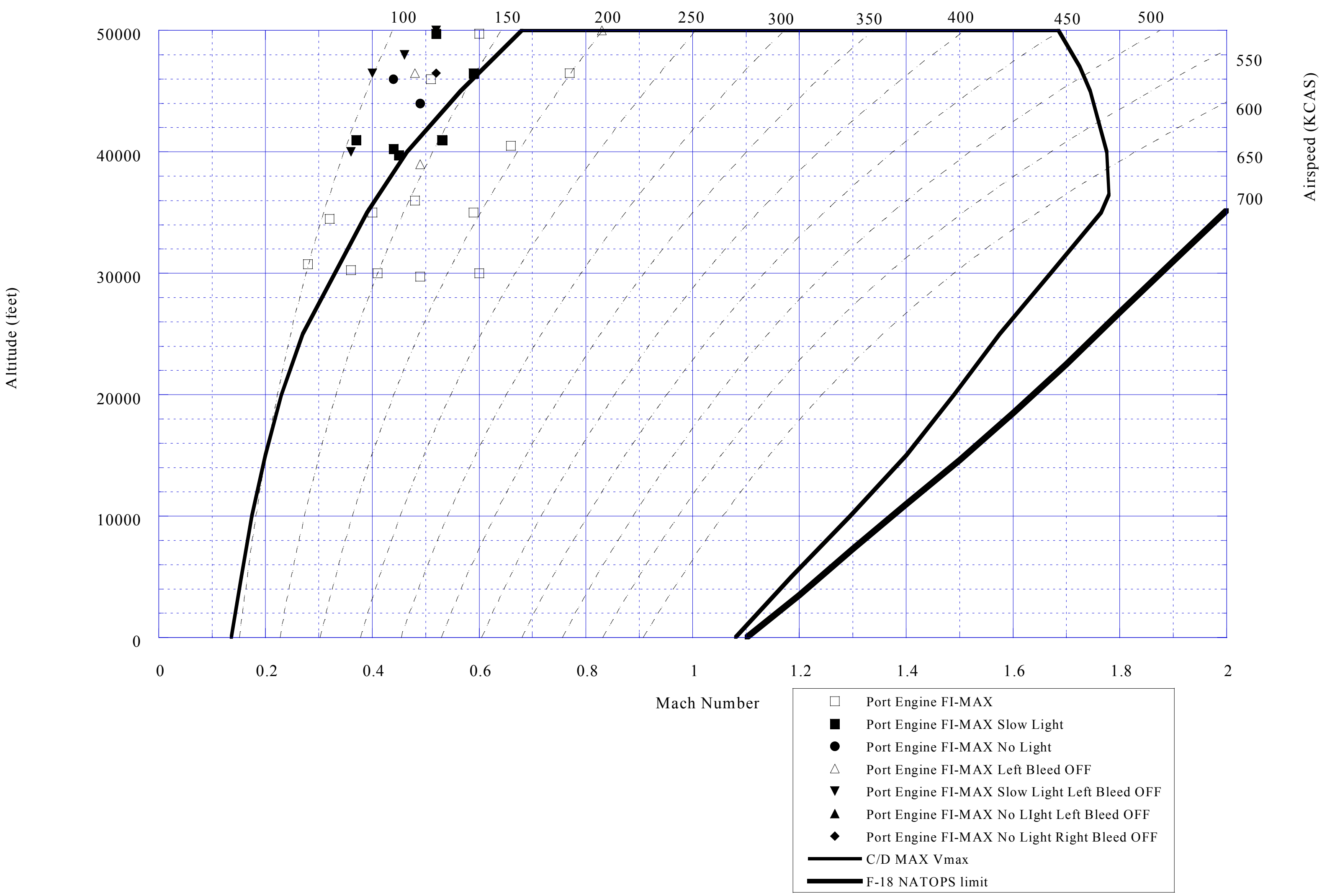


Figure B-19: F/A-18 Flight Envelope with FI-MAX A/B Light-Off Test Points
Port Engine (S/N 360127), Slotted Flameholder (P/N 6056T68G10GI)
Flight Nos. 1, 2, and 3

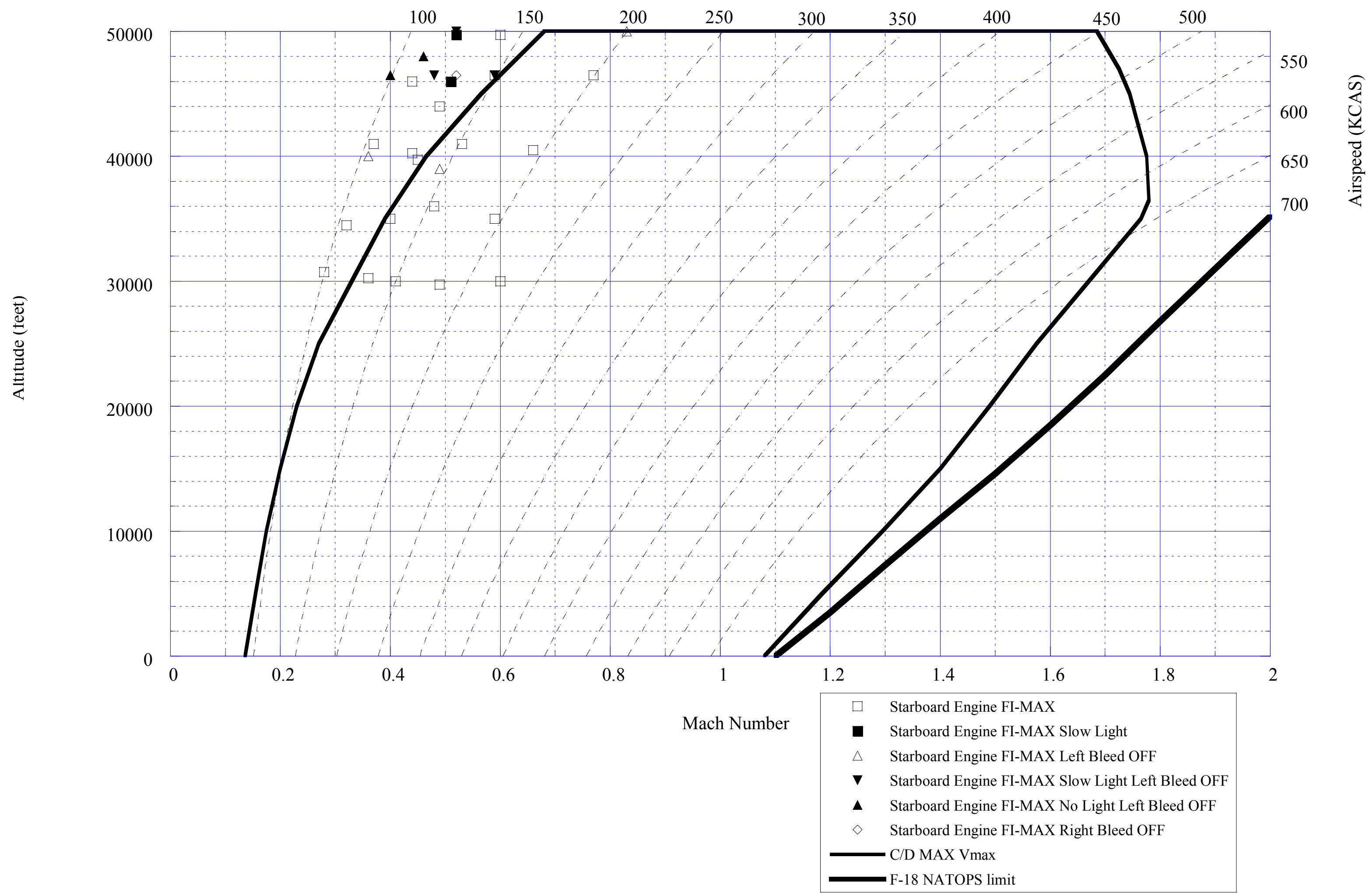


Figure B-20: F/A-18 Flight Envelope with FI-MAX A/B Light-Off Test Points
Starboard Engine (S/N 360408), Production Flameholder (P/N 6056T68G07)
Flight Nos. 1, 2, and 3

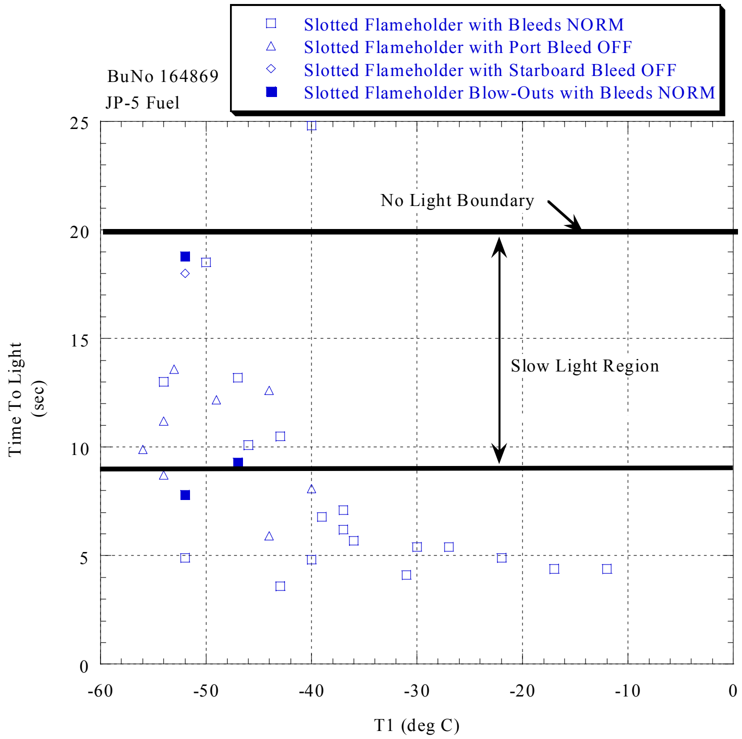


Figure B-21: Time-to-Light Versus Inlet Temperature at Light-Off
Port Engine (S/N 360127)
Slotted Flameholder (P/N 6056T68G10GI)
Flight Nos. 1, 2, and 3
FI-MAX A/B Transients

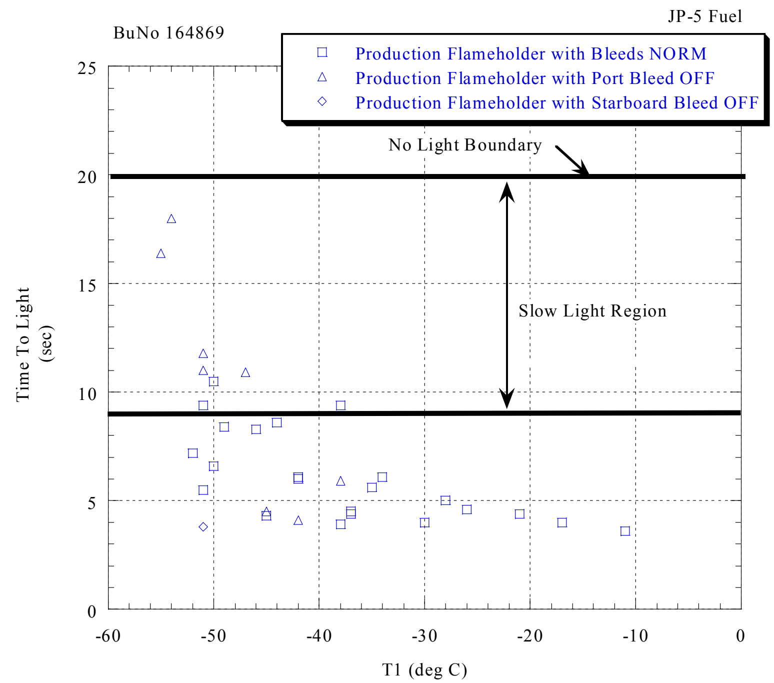


Figure B-22: Time-to-Light Versus Inlet Temperature at Light-Off
Starboard Engine (S/N 360408)
Production Flameholder (P/N 6056T68G07)
Flight Nos. 1, 2, and 3
FI-MAX A/B Transients

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APPENDIX C
INSTALLATION/REMOVAL OF SLOTTED FLAMEHOLDER WITH ENGINE INSTALLED IN AIRCRAFT

REMOVAL OF SLOTTED FLAMEHOLDER

The engine must be cool enough to safely enter the tailpipe.

- The igniter is removed.
- The VEN is in the fully open position.
- A wood plank or padding is inserted in the tailpipe until it is underneath the flameholder assembly.
- A mechanic enters the tailpipe and uses a socket and ratchet wrench to overtorque and break the six attachment bolts which are accessible from the inside of the flameholder.
- The flameholder is slid off the spraybars and out of the tailpipe.

INSTALLATION OF SLOTTED FLAMEHOLDER

To install the slotted flameholder after the initial conversion is complete, the following procedures are followed:

- Six breakable bolts are installed in the flameholder assembly.
- Enter the tailpipe with a screwdriver and six new hook nuts.
- Use the screwdriver to remove old hook nuts from the puck on the support link and replace with a new hook nut.
- Exit tailpipe.
- Slide the new flameholder into the tailpipe until it is positioned behind the spraybars.
- Lift the flameholder up about 2 in. and slide onto spraybars.
- Swing individual support links into place so puck seats into baskets.
- Use breakable bolts in the flameholder to secure the support arm pucks to the flameholder baskets.
- Exit tail pipe.
- Reinstall igniter.

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APPENDIX D
FLIGHT CLEARANCE

ADMINISTRATIVE MESSAGE
PRIORITY

P 282003Z JUL 00 ZYB PSN 339212M20

FM COMNAVAIRSYSCOM PATUXENT RIVER MD//4.0P//

TO NAVSTKAIRTESTRON PATUXENT RIVER MD//55SA10AFA18//

INFO PEOTACAIR PATUXENT RIVER MD//PMA265//
NAVTESTWINGLANT PATUXENT RIVER MD//55TW3AA//
COMNAVAIRSYSCOM PATUXENT RIVER MD//5.0D/4.3//
COMNAVAIRWARCENACDIV PATUXENT RIVER MD//4.11.5.1/4.3.2.6/4.3.2.4//

UNCLAS //N13034//
MSGID/GENADMIN/CONAVAIRSYSCOM/4.0P//

SUBJ/INTERIM FLIGHT CLEARANCE FOR F404-GE-400 OR -402 SLOTTED
/FLAMEHOLDER INSTALLED IN AN F/A-18A/B/C/D.//

REF/A/MSG/NAVTESTWINGLANT/061001ZJUN00//
REF/B/DOC/COMNAVAIRSYSCOM/06SEP95//
NARR/REF A IS FLIGHT CLEARANCE REQUEST. REF B IS NAVAIRSINST
13034.1A, FLIGHT CLEARANCE POLICY FOR MANNED AIR VEHICLES.//

RMKS/1. IRT REF A, FLIGHT CLEARANCE IS GRANTED FOR ONE SLOTTED REMOVABLE FLAMEHOLDER INSTALLED IN AN F404-GE-400 OR -402 ENGINE ON EITHER THE RIGHT OR LEFT SIDE IN F/A-18A/B/C/D AIRCRAFT SUBJECT TO THE CONFIGURATION AND LIMITS BELOW:

2. TAKEOFF CONFIGURATION/LOADING: IAW CURRENT F/A-18A/B/C/D NATOPS/TACMAN WITH THE FOLLOWING EXCEPTIONS/ADDITIONS:
    A. F404-GE-400 OR -402 SLOTTED FLAMEHOLDER INSTALLED.

3. LIMITS: IAW CURRENT F/A-18A/B/C/D NATOPS/TACMAN AND OTHER APPLICABLE NAVAIR FLIGHT CLEARANCES.

4. SPECIAL NOTES, CAUTIONS, AND WARNINGS: NONE.

5. TIME PERIOD: THIS FLIGHT CLEARANCE EXPIRES ON 01 AUG 01.

6. POINTS OF CONTACT:
    PROPULSION IPT / R. LESSEL / 301-757-7590 / LESSELRJ@NAVAIR.NAVY.MIL
    NAVAIRWARCENACDIV 4.11.5.1 / M. PICARD / 301-757-0674 / PICARDMB@NAVAIR.NAVY.MIL
    NAVAIRWARCENACDIV 5.5 / MAJ WHITLEY 301-757-0673.

7. OTHER REMARKS:
    A. THE SLOTTED FLAMEHOLDER IS A CLASS L PART.
    B. UPON SUCCESSFUL COMPLETION OF DEDICATED SLOTTED REMOVABLE FLAMEHOLDER TESTING, OTHER PROJECT FLIGHTS MAY BE FLOWN WITHOUT MONITORING UNTIL AN OPPORTUNE TIME IS AVAILABLE TO REMOVE THE FLAMEHOLDER.
    C. REF B IS PROVIDED FOR GUIDANCE ON STANDARD POLICY AND ASSISTANCE IN PREPARATION OF FUTURE REQUESTS FOR FLIGHT CLEARANCE.//

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APPENDIX E
TABLES

List of Tables

Table E-1: Target Test and Test Conditions
for Slotted Flameholder Test Flight Nos. 1, 2, and 3 on 20 and 21 September 2000
with Slotted Flameholder (P/N 6056T68G10GI) in Port Engine and
Production Flameholder (P/N 6056T68G07) in Starboard Engine

F/A-18C BuNo 164869 — Port ES/N 360127
JP-5 Fuel — Starboard ES/N 360408

Test Point	Altitude(1) (ft Hp)	Airspeed or Mach(2) (KCAS or IMN)	Throttle Transient(3)	Purpose
1	15,000	250	MIL-MAX	Spot check envelope
2	20,000	0.9M	MIL-MAX	Spot check envelope
3, 4 5, 6 7, 8 9, 10 11, 12	30,000	100 125 150 185 225	FI-MAX MIL-MAX	Worst case – GE requested/previous testing
13,14 15,16 17,18 19,20	35,000	100 125 150 200	FI-MAX MIL-MAX	Worst case – left-hand side of envelope
21(4)	35,000	1.5M	MIL-MAX	Spot check envelope
22,23 24, 25 26, 27 28, 29	40,000	100 125 150 200	FI-MAX MIL-MAX	Worst case – GE requested/previous testing
30,31 32,33 34,35 36,37	45,000	100 125 150 200	FI-MAX MIL-MAX	Worst case – left-hand side of envelope
38, 39 40, 41 42, 43 44, 45 46, 47	50,000	100 115 140 165 200	FI-MAX MIL-MAX	Worst case – GE requested/previous testing

NOTES:
(1) Altitude tolerance ±1,000 ft Hp except for 50,000 ft Hp test points which are +0/-2,000 ft Hp.
(2) Airspeed tolerance ±10 KCAS or ±0.05 M.
(3) FI-Flight Idle
MAX-Maximum A/B
MIL – Military Rated Thrust
Transients to be performed on both engines simultaneously with the bleed air in NORM.
(4) Test point not completed.

Table E-2: Target Test and Test Conditions
for Baseline Flight No. 4 on 28 September 2000
with Production (P/N 6056T68G07) Flameholders in Both Engines

F/A-18C BuNo 164869 Port ES/N 360127
JP-5 Fuel Starboard ES/N 360408

Test Point	Altitude[1] (ft Hp)	Airspeed[2] (KCAS)	Throttle Transient[3]	Purpose
3, 4 5, 6 7, 8 9, 10 11, 12	30,000	100 125 150 185 225	FI-MAX MIL-MAX	Worst case – GE requested/previous testing
14 15,16 17,18 19,20	35,000	100 125 150 200	FI-MAX MIL-MAX	Extra baseline test points added due to available fuel. [4]
22,23 24, 25 26, 27 28, 29	40,000	100 125 150 200	FI-MAX MIL-MAX	Worst case – GE requested/previous testing
38, 39 40, 41 42, 43 44, 45 46, 47	50,000	100 115 140 165 200	FI-MAX MIL-MAX	Worst case – GE requested/previous testing

NOTES:
(1) Altitude tolerance ±1,000 ft Hp except for 50,000 ft Hp test points which are +0/-2,000 ft Hp.
(2) Airspeed tolerance ±10 KCAS.
(3) FI-Flight Idle
MAX-Maximum A/B
MIL – Military Rated Thrust
Transients to be performed on both engines simultaneously with the bleed air in NORM.
(4) Test points 14-20 were not initially planned as part of the baseline flight, but were completed due to available fuel.

Table E-3: F/A-18A/B/C/D/F404-GE-400/402 Slotted Flameholder Follow-On
Flight Test Evaluation

Mux Measurand List

Sequence No.	Word Label	Engineering Units	Source[1]	User [1]	Data Name[2]
IASPCV	IAVAL3	counts	ADC	MC	Static Pressure Corrected Valid
IAAMTV	IAVAL4	counts	ADC	MC	Ambient Temperature Valid
IAATMP	IAATMP	°R	ADC	MC	Ambient Temperature
IAIIPR	IAIIPR	in. Hg	ADC	MC	Indicated Impact Pressure
IAIMPR	IAIMPR	in. Hg	ADC	MC	Impact Pressure
IAISPR	IAISPR	in. Hg	ADC	MC	Indicate Static Pressure
IASTPR	IASTPR	in. Hg	ADC	MC	Static Pressure
IALAOA	IALAOA	deg	ADC	MC	Local Angle of Attack (AOA)
IATAOA	IATAOA	deg	ADC	MC	True AOA
IAMACH	IAMACH	mach	ADC	MC	Mach Number
IATASP	IATASP	kt	ADC	MC	True Airspeed
IAIASP	IAIASP	kt	ADC	MC	Indicate Airspeed
IABCAL1	IABCAL	ft	ADC	MC	Barometric-Corrected Pressure Altitude Most Significant Word (MSW)
IABCAL2	IABCAL	ft	ADC	MC	Barometric-Corrected Pressure Altitude Least Significant Word (LSW)
IAPRAL1	IAPRAL	ft	ADC	MC	Pressure Altitude MSW
IAPRAL2	IAPRAL	ft	ADC	MC	Pressure Altitude LSW
IAALRT	IAALRT	ft/min	ADC	MC	Pressure Altitude Rate
IAMHDG	IAMHDG	deg	ADC	MC	Air Data Computer Magnetic Heading
IAFTPR	IADCOD	counts	ADC	MC	Fuel Tanks Pressurized
IARPOS	IADCOD	counts	ADC	MC	Refuel Probe Extended
IABPRS	IABPRS	in. Hg	ADC	MC	Barometric Pressure Setting
IATASS	IATASS	deg	ADC	MC	True Sideslip
IATOPR	IATOPR	in. Hg	ADC	MC	Total Pressure
IARLAA	IARLAA	deg	ADC	MC	Right Local AOA
IALLAA	IALLAA	deg	ADC	MC	Left Local AOA
IATTMP	IATTMP	°R	ADC	MC	Total Temperature
IAITP1	IAITP1	in. Hg	ADC	MC	Indicated Total Pressure
IAMTFV	IAMTFV	none	ADC	MC	Transverse Field Vector
IDHUDR	IDHUDW	counts	MDGML	MC	HUD Symbol Reject
ICAHHM	ICAMD1	counts	FCCA	MC	Heading Hold Engaged
ICAAHM	ICAMD1	counts	FCCA	MC	Attitude Hold Engaged
ICABAH	ICAMD1	counts	FCCA	MC	Barometric Altitude Hold Engaged
ICAHSM	ICAMD1	counts	FCCA	MC	Heading Select Engaged
ICAATC	ICAMD1	counts	FCCA	MC	Auto Throttle Control Engage/Disengage Request
ICAAPC	ICAMD1	counts	FCCA	MC	Auto Pilot Control Request
ICAPRT	ICAPRT	deg/sec	FCCA	MC	Pitch Rate
ICARRT	ICARRT	deg/sec	FCCA	MC	Roll Rate
ICAYRT	ICAYRT	deg/sec	FCCA	MC	Yaw Rate
ICANAC	ICANAC	ft/sec2	FCCA	MC	Normal Acceleration
ICALAC	ICALAC	ft/sec2	FCCA	MC	Lateral Acceleration

Table E-3: (Cont'd)

Sequence No.	Word Label	Engineering Units	Source(1)	User (1)	Data Name(2)
ICAALO	ICAALO	deg	FCCA	MC	FCES Local AOA
ICAATR	ICAATR	deg	FCCA	MC	FCES True AOA
ICAISP	ICAISP	in. Hg	FCCA	MC	Indicated Static Pressure
ICAIIP	ICAIIP	in. Hg	FCCA	MC	Indicated Impact Pressure
ICAPSF	ICAPSF	in.	FCCA	MC	Longitudinal Stick Position
ICARSF	ICARSF	in.	FCCA	MC	Lateral Stick Position
ICARPF	ICARPF	lb	FCCA	MC	Rudder Pedal Force
ICALFC	ICALFC	deg	FCCA	MC	Dial-A-Function Table Command
OCATAS	OCATAS	kt	MC	FCCA	True Airspeed
ICBWRG	ICBILD	counts	FCCB	MC	Weight On Wheels (WOW)
ICBLEN	ICBILD	counts	FCCB	MC	Left Engine Compressor Speed Lockup
ICBLEB	ICBILD	counts	FCCB	MC	Left Engine Bleed Door Closed
ICBREN	ICBILD	counts	FCCB	MC	Right Engine Compressor Speed Lockup
ICBREB	ICBILD	counts	FCCB	MC	Right Engine Bleed Door Closed
ICBPLL	ICBPLL	deg	FCCB	MC	Power Lever Angle Left(3)
ICBPLR	ICBPLR	deg	FCCB	MC	Power Lever Angle Right(3)
ICBLTP	ICBLTP	deg	FCCB	MC	Left Trailing Edge Flap (TEF) Position
ICBRTP	ICBRTP	deg	FCCB	MC	Right TEF Position
ICBILF	ICBILF	deg	FCCB	MC	Left Inboard Leading Edge Flap (LEF) Position
ICBLLO	ICBLLO	deg	FCCB	MC	Left Outboard LEF Position
ICBRLO	ICBRLO	deg	FCCB	MC	Right Outboard LEF Position
ICBLSP	ICBLSP	deg	FCCB	MC	Left Stabilator Position
ICBRSP	ICBRSP	deg	FCCB	MC	Right Stabilator Position
ICBLAP	ICBLAP	deg	FCCB	MC	Left Aileron Position
ICBRAP	ICBRAP	deg	FCCB	MC	Right Aileron Position
ICBLRP	ICBLRP	deg	FCCB	MC	Left Rudder Position
ICBRRP	ICBRRP	deg	FCCB	MC	Right Rudder Position
ICBD06	ICBSDD	counts	FCCB	MC	Right Main Landing Gear (MLG) Down and Locked
ICBD07	ICBSDD	counts	FCCB	MC	Left MLG Down and Locked
ICBD08	ICBSDD	counts	FCCB	MC	Right MLG WOW
ICBD10	ICBSDD	counts	FCCB	MC	Nose Landing Gear (NLG) WOW
ICBD11	ICBSDD	counts	FCCB	MC	NLG Down and Locked
ICBD12	ICBSDD	counts	FCCB	MC	APC Engaged
ICBD13	ICBSDD	counts	FCCB	MC	Launch Bar Down
ICBD14	ICBSDD	counts	FCCB	MC	Left MLG WOW
ICBIRF	ICBIRF	deg	FCCB	MC	Right Inboard LEF Position
IEEGTL	IEEGTL	°C	SDC	MC	Left EGT
IECDPL	IECDPL	psia	SDC	MC	Left Compressor Discharge Pressure(3)
IETDPL	IETDPL	psia	SDC	MC	Left Turbine Discharge Pressure
IEXNLL	IEXNLL	revs/min	SDC	MC	Left Low Pressure Rotor Speed
IEXNHL	IEXNHL	revs/min	SDC	MC	Left High Pressure Rotor Speed
IEEGTR	IEEGTR	°C	SDC	MC	Right EGT
IECDPR	IECDPR	psia	SDC	MC	Right Compressor Discharge Pressure(3)
IETDPR	IETDPR	psia	SDC	MC	Right Turbine Discharge Pressure
IEXNLR	IEXNLR	revs/min	SDC	MC	Right Low Pressure Rotor Speed

Table E-3: (Cont'd)

Sequence No.	Word Label	Engineering Units	Source(1)	User (1)	Data Name(2)
IEXNHR	IEXNHR	revs/min	SDC	MC	Right High Pressure Rotor Speed
IEIICE	IEDI04	counts	SDC	MC	Inlet Ice Detected
IERCTH	IEDI05	counts	SDC	MC	RLCS Temperature High
IEBALD	IEDI06	counts	SDC	MC	Bleed Air Leak Detector
IESBAO	IEDI06	counts	SDC	MC	SCN Bleed Air Overpressure
IEC110	IEDI07	counts	SDC	MC	Left Bleed Off
IEC111	IEDI07	counts	SDC	MC	Right Bleed Off
IEEITL	IEEITL	°C	SDC	MC	Light Engine Inlet Temperature
IELOPL	IELOPL	psid	SDC	MC	Left Engine Oil Pressure
IENOZL	IENOZL	pct.	SDC	MC	Left Engine Nozzle Position
IEMEFL	IEMEFL	pph	SDC	MC	Left Main Fuel Flow
IEFITL	IEFITL	°C	SDC	MC	Left Fuel Inlet Temperature
IES5V1	IES5V1	°C	SDC	MC	Left Turbine Discharge Temperature
IEEITR	IEEITR	°C	SDC	MC	Right Engine Inlet Temperature
IELOPR	IELOPR	psid	SDC	MC	Right Engine Oil Pressure
IENOZR	IENOZR	pct.	SDC	MC	Right Engine Nozzle Position
IEMEFR	IEMEFR	pph	SDC	MC	Right Main Fuel Flow
IEFITR	IEFITR	°C	SDC	MC	Right Fuel Inlet Temperature
IES5V2	IES5V2	°C	SDC	MC	Right Turbine Discharge Temperature
IEFQTT	IEFQTT	lb	SDC	MC	Fuel Quantity Total
IECQT1	IECQT1	lb	SDC	MC	Tank 1 Corrected Fuel Quantity
IECQT2	IECQT2	lb	SDC	MC	Tank 2 Corrected Fuel Quantity
IECQT3	IECQT3	lb	SDC	MC	Tank 3 Corrected Fuel Quantity
IECQT4	IECQT4	lb	SDC	MC	Tank 4 Corrected Fuel Quantity
IEWTCL	IEWTCL	lb	SDC	MC	Left Wing Corrected Fuel Quantity
IEWTCR	IEWTCR	lb	SDC	MC	Right Wing Corrected Fuel Quantity
IEETCC	IEETCC	lb	SDC	MC	Center External Corrected Fuel Quantity
IEETCL	IEETCL	lb	SDC	MC	Left External Corrected Fuel Quantity
IEETCR	IEETCR	lb	SDC	MC	Right External Corrected Fuel Quantity
IETICQ	IETICQ	lb	SDC	MC	Total Internal Corrected Fuel Quantity
IETTCQ	IETTCQ	lb	SDC	MC	Total Corrected Fuel Quantity
INRRWB	INRRWB	deg/sec	INS	MC	Roll Rate Wide Band
INYRWB	INYRWB	deg/sec	INS	MC	Yaw Rate Wide Band
INTHDG	INTHDG	deg	INS	MC	True Heading
INPTCH	INPTCH	deg	INS	MC	Pitch
INOROL	INOROL	deg	INS	MC	Outer Roll
INIROL	INIROL	deg	INS	MC	Inner Roll
INEVEL	INEVEL	ft/sec	INS	MC	East/West Velocity
INNVEL	INNVEL	ft/sec	INS	MC	North/South Velocity
INVVEL	INVVEL	ft/sec	INS	MC	Vertical Velocity
INBIAL1	INBIAL	ft	INS	MC	Barometric Inertial Altitude MSW
INBIAL2	INBIAL	ft	INS	MC	Barometric Inertial Altitude LSW
INPLAT1	INPLAT	deg	INS	MC	Present Position Latitude MSW
INPLAT2	INPLAT	deg	INS	MC	Present Position Latitude LSW
INPLON1	INPLON	deg	INS	MC	Present Position Longitude MSW
INPLON2	INPLON	deg	INS	MC	Present Position Longitude LSW
INEACC	INEACC	ft/sec^2	INS	MC	East/West Acceleration

Table E-3: (Cont'd)

Sequence No.	Word Label	Engineering Units	Source[(1)]	User [(1)]	Data Name[(2)]
INNACC	INNACC	ft/sec^2	INS	MC	North/South Acceleration
INVACC	INVACC	ft/sec^2	INS	MC	Vertical Acceleration
INLATA	INLATA	ft/sec^2	INS	MC	Lateral Acceleration
INLONA	INLONA	ft/sec^2	INS	MC	Longitudinal Acceleration
INNRMA	INNRMA	ft/sec^2	INS	MC	Normal Acceleration
INRRNB	INRRNB	deg/sec	INS	MC	Roll Rate Narrow Band
INPRNB	INPRNB	deg/sec	INS	MC	Pitch Rate Narrow Band
INYRNB	INYRNB	deg/sec	INS	MC	Yaw Rate Narrow Band
ORWNDN	ORWNDN	ft/sec	MC	RDR	North Wind
ORWNDE	ORWNDE	ft/sec	MC	RDR	East Wind
ORWNDD	ORWNDD	ft/sec	MC	RDR	Vertical Wind
O1MV33	O1MV33	none	MC	MC1L	MC2 Internal Variable 33
O1MV34	O1MV34	none	MC	MC1L	MC2 Internal Variable 34
O1MV37	O1MV37	none	MC	MC1L	MC2 Internal Variable 37
O1MV45	O1MV45	none	MC	MC1L	MC2 Internal Variable 45
O1MV52	O1MV52	none	MC	MC1L	MC2 Internal Variable 52
O1MV53	O1MV53	none	MC	MC1L	MC2 Internal Variable 53
O1MV54	O1MV54	none	MC	MC1L	MC2 Internal Variable 54

NOTES:
(1) MC – Mission Computer; INS – Inertial Navigation System, RDR - Radar; SDC – Signal Data Computer; FCCA – Flight Control Computer A; FCCB – Flight Control Computer B; MDGML – Multipurpose Display Group; ADC – Air Data Computer; MC1L – Mission Computer 1
(2) Sample rate was 20 samples/sec for all parameters.
(3) Safety of flight parameters. Additional safety of flight parameters included (from any valid source): hot mic, altitude, mach, EGT, and either core speed or fan speed.

Table E-4: F/A-18A/B/C/D/F404-GE-400/402 Slotted Flameholder Follow-On Flight Test Evaluation

Hazard Analysis

Hazard Description	Cause	Resulting Hazard Effect	Preventative Measures	Corrective Action	Residual Hazard Level[1]	Risk Category[2]
Things Falling off Aircraft – Flameholder	-Design or material flaw in new flameholder	-Loss of A/B -Damage to personnel/property on the ground -Damage to VEN system causing VEN not to schedule properly	-Flameholder will be visually inspected prior to each test flight to ensure no obvious cracks or damage beyond limits exists. - Slotted flameholder has been extensively tested by GE to failure and failure modes are understood.	-Return to Base -Do not select A/B -For VEN system, problem leave throttle fixed at idle. -NATOPS procedures for engine malfunctions	III-D	A
Engine Flameout (High altitude)	- Stall induced combustor instability at high altitudes due to rapid throttle movements	-Engine speed rollback, followed auto relight which results in a hot start or overtemp.	-Brief pilot to avoid unnecessary throttle chops with quick readvances while testing at 50,000 ft Hp. -Risk is mitigated by real-time telemetry engine monitoring. -Engineers will monitor engine relight sequence to ensure overtemp is avoided. -Throttle of affected engine will be shutoff until within the crossbleed or windmill start envelope.	NATOPS Emergency Procedures.	IV-C	A

Table E-4: (Cont'd)

Hazard Description	Cause	Resulting Hazard Effect	Preventative Measures	Corrective Action	Residual Hazard Level[(1)]	Risk Category[(2)]
Departure from controlled flight due to A/B no light or blowout	Asymmetric thrust	Out of control flight	-Excessive blowouts will be avoided. After it is determined that a stable A/B light is not achieved, the test point will be knocked off. -The pilot will be briefed that a no light or blowout may occur and to expect thrust asymmetry. -High altitude testing will minimize thrust asymmetry. -If blowout or no light is detected: 1) Counter resulting yaw with rudder 2) If unable to counter yaw throttle to idle and unload AOA.	NATOPS out of control procedures	IV-D	A
Engine overspeed due to A/B blowout	A/B blowout in conjunction with an ECA malfunction	-Damage to engine	-ECA has control logic built into it to prevent overspeeds due to A/B blowouts. -Propulsion engineer will be monitoring basic engine parameters.	NATOPS Overspeed Emergency procedures	III-D	A

NOTES: (1) The Residual Hazard Level is comprised of two parts, the Hazard Severity and the Mishap Probability. These are defined below:

Hazard Severity

- I - Catastrophic – May cause death or aircraft loss.
- II – Critical – May cause severe injury or major aircraft damage.
- III - Marginal – May cause minor injury or minor aircraft damage.
- IV – Negligible – Will not result in injury or aircraft damage.

Mishap Probability

- A – Frequent – Likely to occur immediately or within a short period of time.
- B – Probable – Probably will occur in time.
- C – Occasional – May occur in time.
- D – Remote – Unlikely to occur.

(2) The Risk Category is based upon the combination of the Hazard Severity and Mishap Probably. A Risk Category A is defined as "Test or activities that present no greater risk than normal operations".

Table E-5: Time-To-Light for Baseline – Flight No. 4 on 28 September 2000
with Production (P/N 6056T68G07) Flameholders in Both Engines Bleed Air Norm for All Test Points

F/A-18C BuNo 164869 — Port ES/N 360127
JP-5 Fuel — Starboard ES/N 360408

		At MAX A/B Selection							At A/B Light-off (for slow or no lights)			
Throttle Transient[1]	Test Point	Altitude (ft Hp)	Airspeed (KCAS)	Mach (IMN)	Port Time-to-Light[2] (sec)	Starboard Time-to-Light[2] (sec)	Port T1 (°C)	Starboard T1 (°C)	Altitude (ft Hp)	Airspeed (KCAS)	T1[3] (°C)	Comments
	11	31,000	235	0.64	4.0	3.9	-23	-22	-	-	-	
	9	30,750	185	0.51	4.0	3.9	-29	-28	-	-	-	
	7	31,000	150	0.42	4.6	5.0	-33	-32	-	-	-	
	5	31,000	130	0.36	4.7	4.6	-35	-34	-	-	-	
	3	30,000	105	0.29	6.3	4.8	-36	-34	-	-	-	
	19	35,750	195	0.60	5.0	3.6	-32	-31	-	-	-	
	17	36,000	155	0.48	4.7	4.2	-37	-36	-	-	-	
	15	35,000	130	0.40	6.8	4.8	-42	-40	-	-	-	
FI-MAX A/B	28	41,000	200	0.69	4.8	4.2	-28	-27	-	-	-	
	26	40,250	160	0.71	7.0	7.0	-35	-35	-	-	-	
	24	39,750	130	0.45	**9.6**	4.2	-41	-38	39,000	130	-41	Port slow light
	22	41,000	100	0.36	8.0	4.8	-40	-42	-	-	-	
	46	49,000	195	0.80	7.0	6.3	-31	-30	-	-	-	
	44	49,750	155	0.66	**13.6**	8.9	-38	-38	49,000	160	-38	Port slow light
	44R1	48,250	155	0.64	4.2	7.1	-38	-38	-	-	-	TP knocked off as aircraft exceeded the test tolerance
	44R2	50,000	160	0.68	5.6	4.1	-37	-36	-	-	-	
	42	48,250	140	0.58	7.6	7.5	-43	-42	-	-	-	
	40	48,250	115	0.48	**No Light**	7.0	-48	-46	-		-	Test point knocked off at 19 seconds

Table E-5: (Cont'd)

Throttle Transient(1)	Test Point	At MAX A/B Selection: Altitude (ft Hp)	Airspeed (KCAS)	Mach (IMN)	Port Time-to-Light(2) (sec)	Starboard Time-to-Light(2) (sec)	Port T1 (°C)	Starboard T1 (°C)	At A/B Light-off (for slow or no lights): Altitude (ft Hp)	Airspeed (KCAS)	T1(3) (°C)	Comments
FI-MAX A/B	40R1	49,750	120	0.52	**11.6**		-47		48,000	120	-47	Port slow light
						11.8		-45	48,000	120	-46	Starboard slow light
	38	49,750	110	0.48	**13.6**	7.7	-47	-46	49,000	105	-48	Port slow light
MIL-MAX A/B	12	31,000	225	0.62	1.5	0.8	-26	-26	-	-	-	
	10	31,000	180	0.50	2.0	0.8	-32	-32	-	-	-	
	8	30,500	150	0.41	**6.1**	**6.1**	-35	-34	-	-	-	
	6	30,000	120	0.33	0.8	0.9	-37	-35	-	-	-	
	4	29,500	95	0.26	1.2	0.8	-37	-36	-	-	-	
	20	36,000	205	0.63	2.4	0.9	-32	-32	-	-	-	
	18	35,500	150	0.46	1.2	0.8	-39	-38	-	-	-	
	16	34,500	125	0.38	0.8	1.6	-44	-42	-	-	-	
	14	34,000	105	0.32	1.2	1.6	-45	-44	-	-	-	
	29	40,750	205	0.70	0.8	0.8	-29	-29	-	-	-	
	27	40,000	155	0.69	0.8	1.2	-38	-36	-	-	-	
	25	40,500	130	0.45	0.7	1.1	-42	-40	-	-	-	
	23	39,500	100	0.34	1.8	0.8	-43	-42	-	-	-	
	47	48,000	190	0.61	0.7	1.2	-33	-32	-	-	-	
	45	48,500	155	0.64	2.6	1.2	-40	-38	-	-	-	
	43	48,750	135	0.57	0.9	1.7	-45	-43	-	-	-	
	41	50,000	125	0.54	5.5	2.4	-47	-46	-	-	-	
	39	49,750	110	0.48	2.7	1.2	-47	-46	-	-	-	

NOTES: (1) FI- Flight Idle; MAX A/B – Maximum A/B; MIL – Military Rated Thrust.
(2) Bolded times to light indicate slow lights or no lights.
(3) T1 – inlet temperature – T1 shown is for the engine with the slow light as denoted in the comments column.

Table E-6: Time-to-Light for Slotted Flameholder Test Flight Nos. 1, 2, and 3 on 20-21 September 2000 with Slotted Flameholder (P/N 6056T68G10GI) in Port Engine and Production Flameholder (P/N 6056T68G07) in Starboard Engine

F/A-18C BuNo 164869 — Port ES/N 360127
JP-5 Fuel — Starboard ES/N 360408

		At MAX A/B Selection								At A/B Light-off (for slow or no lights)			
Throttle Transient(1)	Test Point	Altitude (ft Hp)	Airspeed (KCAS)	Mach (IMN)	Bleed Air	Port Time-to-Light(2) (sec)	Starboard Time-to-Light(2) (sec)	Port T1 (°C)	Starboard T1 (°C)	Altitude (ft Hp)	Airspeed (KCAS)	T1(3) (°C)	Comments
FI-MAX A/B	11	30,000	220	0.60	Norm	4.4	3.6	-12	-11	-	-	-	
	9	29,750	180	0.49	Norm	4.4	4.0	-17	-17	-	-	-	
	7	30,000	150	0.41	Norm	4.9	4.4	-22	-21	-	-	-	
	5	30,250	130	0.36	Norm	5.4	4.6	-27	-26	-	-	-	
	3	30,750	100	0.28	Norm	5.4	5.0	-30	-28	-	-	-	
	19	35,000	195	0.59	Norm	4.1	4.0	-31	-30	-	-	-	
	17	36,000	155	0.48	Norm	6.2	4.4	-37	-37	-	-	-	
	15	35,000	130	0.40	Norm	6.8	4.5	-39	-37	-	-	-	
	13	34,500	105	0.32	Norm	4.8	3.9	-40	-38	-	-	-	
	28	40,500	195	0.66	Norm	5.7	6.1	-36	-34	-	-	-	
	26	41,000	150	0.53	Norm	**10.5**	6.1	-43	-42	40,250	160	-43	
	26R1	39,000	145	0.49	L Off	5.9	4.1	-44	-42	-	-	-	
	24	40,250	125	0.44	Norm	**9.3**	4.3	-47	-45	39,250	130	-47	One port blowout
	22	41,000	105	0.37	Norm	**18.5**	8.4	-50	-49	38,500	120	-49	
	22R1	40,000	105	0.36	L Off	**12.6**	4.5	-44	-45	38,000	125	-44	
	36	46,500	200	0.77	Norm	7.1	5.6	-37	-35	-	-	-	
	34	46,500	150	0.59	Norm	**13.2**	8.3	-47	-46	45,750	150	-47	
	34R1	46,500	150	0.59	L Off	**12.2**		-49		45,500	155	-48	Port slow light
							10.9		-47	45,500	155	-46	Starboard slow light
	32	46,000	130	0.51	Norm	7.8		-52		45,500	130	-53	One port blowout
							10.5		-50	45,000	130	-51	Starboard slow light
	32R1	46,500	120	0.48	L Off	8.7	**11.8**	-54	-51	45,000	125	-51	Starboard slow light
	30	46,000	110	0.44	Norm	**25.3**	7.2	-54	-52	42,000	130	-50	Two port blowouts
	30R1	46,500	100	0.40	L Off	**9.9**		-56		45,000	105	-55	Port slow light
							16.4		-55	44,000	110	-51	Starboard slow light

Table E-6: (Cont'd)

Throttle Transient(1)	Test Point	At MAX A/B Selection								At A/B Light-off (for slow or no lights)			Comments
		Altitude (ft Hp)	Airspeed (KCAS)	Mach (IMN)	Bleed Air	Port Time-to-Light(2) (sec)	Starboard Time-to-Light(2) (sec)	Port T1 (°C)	Starboard T1 (°C)	Altitude (ft Hp)	Airspeed (KCAS)	T1(3) (°C)	
FI-MAX A/B	24	39,750	130	0.45		**10.1**	8.6	-46	-44	38,000	135	-44	
	46	50,250	195	0.82	Norm	**24.8**		-40		49,750	190	-42	Port slow light
							9.4		-38	50,000	190	-40	Starboard slow light
	46R1	50,000	200	0.83	L Off	8.1	5.9	-40	-38	-	-	-	
	44	50,250	170	0.72	Norm	3.6	6.0	-43	-42	-	-	-	
	42	49,750	140	0.60	Norm	4.9	6.6	-52	-50	-	-	-	
	40	49,750	120	0.52	Norm	**13.0**		-54		48,500	120	-55	Port slow light
							9.4		-51	49,000	120	-52	Starboard slow light
	40R1	50,000	120	0.52	L Off	**13.6**		-53		49,000	120	-54	Port slow light
							11.0		-51	49,000	120	-53	Starboard slow light
	38	44,000	130	0.49	Norm	**18.8**	5.5	-52	-51	40,500	180	-44	Two port blowouts
	32**R2**	46,500	130	0.52	R Off	**18.0**	3.8	-52	-51	46,000	120	-55	
	38R1	48,000	110	0.46	L Off	**11.2**		-54		46,500	100	-56	Port slow light
							18.0		-54	45,250	105	-55	Starboard slow light
MIL-MAX A/B	1	14,250	250	0.49	Norm	0.5	0.4	17	17	-	-	-	
	2	20,000	430	0.91	Norm	0.4	0.3	35	35	-	-	-	
	12	30,000	225	0.61	Norm	0.6	0.9	-14	-13	-	-	-	
	10	29,500	185	0.50	Norm	1.5	0.8	-20	-20	-	-	-	
	8	29,000	150	0.40	Norm	1.1	0.7	-23	-22	-	-	-	
	6	29,250	130	0.35	Norm	0.7	0.6	-26	-24	-	-	-	
	4	29,500	105	0.29	Norm	2.3	0.7	-29	-26	-	-	-	
	20	35,000	200	0.60	Norm	0.8	1.1	-30	-30	-	-	-	
	18	35,500	155	0.48	Norm	1.8	0.7	-38	-38	-	-	-	
	16	35,500	125	0.39	Norm	1.2	1.0	-41	-39	-	-	-	
	14	36,000	105	0.33	Norm	1.9	0.8	-44	-41	-	-	-	
	29	40,250	205	0.69	Norm	1.7	0.7	-35	-34	-	-	-	
	27	40,250	145	0.50	Norm	2.9	0.8	-44	-43	-	-	-	
	25	41,000	125	0.44	Norm	**8.3**	2.2	-49	-47	40,000	140	-47	One port blowout

Table E-6: (Cont'd)

		At MAX A/B Selection								At A/B Light-off (for slow or no lights)			
Throttle Transient[1]	Test Point	Altitude (ft Hp)	Airspeed (KCAS)	Mach (IMN)	Bleed Air	Port Time-to-Light[2] (sec)	Starboard Time-to-Light[2] (sec)	Port T1 (°C)	Starboard T1 (°C)	Altitude (ft Hp)	Airspeed (KCAS)	T1[3] (°C)	Comments
MIL-MAX A/B	25R1	40,000	130	0.45	L Off	1.9	2.4	-47	-46	-	-	-	
	NA	40,500	130	0.45	Norm	4.6	1.6	-48	-46	40,500	130	-48	One blowout on port engine not during a test point.
MIL-MAX A/B	23	41,250	110	0.39	Norm	5.4	**12.9**	-51	-49	39,500	105	-47	Starboard slow light
	23R1	41,000	105	0.37	Norm	**17.7**	2.3	-49	-47	38,000	150	-44	
	37	46,000	205	0.78	Norm	3.3	0.8	-37	-36	-	-	-	
	35	44,750	155	0.59	Norm	2.4	2.0	-46	-44	-	-	-	
	33	43,500	130	0.48	Norm	4.6	1.7	-52	-50	43,000	130	-52	One port blowout
	33R1	44,000	135	0.50	L Off	1.7	2.8	-52	-50	-	-	-	
	31	46,000	105	0.42	Norm	4.4	2.1	-55	-52	45,750	105	-55	One port blowout
	31R1	45,500	105	0.41	L Off	**10.3**		-54		44,000	100	-54	Port slow light
							9.3		-52	44,500	100	-52	Starboard slow light
	47	49,250	190	0.78	Norm	0.8	0.8	-42	-40	-	-	-	
	45	50,250	170	0.72	Norm	1.2	1.2	-46	-45	-	-	-	
	43	48,000	145	0.59	Norm	4.8	0.9	-52	-50	-	-	-	
	41	49,750	125	0.54	Norm	1.2	4.0	-52	-52	-	-	-	
	39	48,500	110	0.46	Norm	4.5	1.1	-55	-54	-	-	-	
MIL-MIN A/B	30M	44,000	105	0.40	Norm	5.3	1.3	-56	-55	43,250	110	-57	One port blowout
	26M	41,000	155	0.54	Norm	3.8	1.1	-42	-40	--	--	--	
	22M	39,500	110	0.38	Norm	3.8	0.6	-48	-46	-	-	-	Not stabilized at MIL before test point. Selected Max A/B then brought back to MIL before selecting Min A/B.
	34M	46,500	150	0.59	Norm	0.7	2.3	-50	-49	-	-	-	

NOTES: (1) FI- Flight Idle; MAX A/B – Maximum A/B; MIL – Military Rated Thrust; Min A/B – Minimum A/B.
(2) Bolded times to light indicate slow lights or no lights.
(3) T1 – inlet temperature – T1 shown is for the engine with the slow light as denoted in the comments column.

APPENDIX F
LESSONS LEARNED

BASELINE TESTING

1. Baseline testing was conducted after the slotted flameholder testing for schedule conveniences. Previously, baseline testing was conducted first and the baseline test matrix covered a range of test conditions. However, by conducting the baseline test after test hardware flights, additional information about the slotted flameholder operability was obtained before the baseline was flown. Testing at these conditions would provide more inclusive data. Some of the typical baseline test conditions where the slotted flameholder had no issues could be swapped with other areas where the slotted flameholder was slower to light-off. This would provide a better comparison between the slotted flameholder and the production flameholder installed in the same engine. For future flight tests, where the baseline flight is flown after test flights, recommend taking into account the results from the test flights to better target test points for the baseline flight.

INLET TEMPERATURE

2. During the baseline testing, the inlet temperature was warmer than the desired temperature. Test points could have been repeated with the bleed air OFF on the starboard engine to provide the port engine with a more severe environment similar to decreasing inlet temperature, thus making the same test conditions for the production comparable to the slotted flameholder. Unfortunately, this did not occur and the baseline flight could only be used as comparison to the slotted flameholder down to the inlet temperature seen during the baseline flight. Any colder test points on the slotted flameholder could only be compared to the opposite engine at the same test point. The baseline flight would have provided data for comparison to more test conditions had the flight been conducted in a similar environment to which the slotted flameholder was exposed. Recommend for future flameholder flight tests that baseline and test flights be conducted with similar inlet temperatures and, if not possible, for the flights not meeting the inlet temperature criteria repeat test points simulating a colder inlet temperature by turning the appropriate bleed air OFF.

FLIGHT TEST TECHNIQUE

3. Flight test technique from the previous test and lessons learned were incorporated into these flight tests. A more refined technique was developed and is described below for use on future flameholder or similar flight tests.

4. Using a MIL power climb between test points for the 35,000 ft and lower points was effective; however, MAX A/B was used to achieve the test points above 35,000 ft. The faster points (200-140 KCAS) could all be completed in one run starting at the high end of the test band and finishing by the lower end of the altitude band. The remaining points (125-100 KCAS) were accomplished by climbing approximately 1,000 ft above the test band (except the 50,000 points) and then slowing to the test airspeed descending through the altitude band. Due to the faster light-off times from MIL-MAX A/B, the most efficient order to perform the throttle transients was to perform the MIL-MAX A/B first and then FI-MAX A/B. After completing the FI-MAX A/B test point, the aircraft was generally below the test altitude band. The best method to return to the test altitude was to keep the throttles in MAX A/B, reset the bleed air knob to NORM, if required, relax the AOA to approximately 4-5 deg, accelerate to 280-300 KCAS and then establish a 3-5 deg noseup climb. The pilot then determined the best point to come out of A/B and convert airspeed to altitude for the next test point. Note at the 100 KCAS points, the AOA was above 35 deg (i.e., AOA tone was present) and a slight roll off was observed. This was easily countered with opposite rudder to bring the aircraft back to a wings level attitude.

BLEED AIR SETTING

5. Test points were performed with the bleed air setting in NORM and repeated with bleed air in OFF if an anomaly occurred. The bleed air split between engines is unknown and inconsistent in the NORM setting. Since bleed air has a significant affect on A/B light-off it would have been more accurate to perform the test points one engine at a time with the bleed air OFF on the test engine. This would have eliminated the bleed variations between test points. The drawback to this method is twice the number of test points would be required. Also, test points would be performed at a more severe condition that would not be fleet representative. However, if anomalies were discovered the test point could be repeated with bleed air NORM to determine if the problem also exists in a more fleet representative configuration. While these tests did not require the accuracy or allow for the additional flight costs this method should be considered for future flight tests.

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